REF 03-RF-01471, JLB-094-03

Draft Final
Comprehensive Risk Assessment
Work Plan and Methodology

September 2003

ADMIN RECORD
SW-A-004835

DOCUMENT CLASSIFICATION
REVIEW WAIVER PER
CLASSIFICATION OFFICE

1/109

TABLE OF CONTENTS

1 0	INTRODUCTION	1
1 1	CRA Scope	2
1 2	Technical Approach	2
2 0	HUMAN HEALTH SCM	3
2 1	Receptors	5
2 2	Human Health Exposure Scenarios	7
2 2 1	WRW Exposure Scenario	7
2 2 2	WRV Exposure Scenario	8
3 0	DATA COLLECTION AND EVALUATION	10
3 1	HHRA DQOs	10
3 1 1	Step 1 State the Problem	11
3 1 2	Step 2 Identify the Decision	11
3 1 3	Step 3 Identify the Inputs to the Decision	11
3 1 4	Step 4 Define Study Boundaries	12
3 1 5	Step 5 Identify the Data Adequacy Decision Rules	12
3 1 6	Step 6 Specify Tolerable Limits on Decision Errors	15
3 1 7	Step 7 Optimize the Design	15
4 0	HHRA EXPOSURE ASSESSMENT	15
4 1	Exposure Factors	15
4 1 1	Exposure Pathway Assessment	15
4 1 2	WRW Scenario Exposure Factors	17
4 1 3	WRV Scenario Exposure Factors	18
4 2	Functional EUs and AOCs	19
4 2 1	EU Development	19
4 2 2	Defining and Assessing EUs	19
4 2 3	EUs for the WRW	27
4 2 4	EUs for the WRV	27
4 2 5	Defining and Assessing AOCs	28
4 3	Data Aggregation for Risk Assessment	29
4 4	COC Identification and Selection	29
4 4 1	Selection of EU and AOC COCs	29
4 4 2	DQA	31
4 4 3	Data Aggregation	31
4 4 4	Elimination of Essential Nutrients/Major Cations and Anions	31
4 4 5	PRG Screen	31
4 4 6	Detection Frequency Filter	32
4 4 7	Data Distribution Testing	32
4 4 8	Background Analysis	32
4 4 9	Professional Judgment	33
4 4 10	Presentation of COCs	33
4 5	Pathway Significance Evaluations	34
4 5 1	Groundwater-to-Surface Water Pathway	34
4 5 2	Groundwater/Subsurface Soil-to-Air Pathway	35
4 6	EPCs	35

4 6 1	Intake Calculations	36
5 0	HUMAN HEALTH TOXICITY ASSESSMENT	38
5 1	Identification of Toxicity Values for Carcinogenic Effects	39
5 1 1	Chemical Carcinogens.	39
5 1 2	Radionuclides	40
5 2	Identification of Toxicity Values for Noncarcinogenic Effects	40
5 3	Dermal Exposure to Chemicals	48
5 4	Identification of Radionuclide Dose Conversion Factors	48
6 0	HUMAN HEALTH RISK CHARACTERIZATION PERFORMED ON AN EU AND AOC BASIS	49
6 1	Calculating and Characterizing Carcinogenic Effects	49
6 2	Calculating and Characterizing Noncarcinogenic Effects	50
6 3	Dermal Assessment	52
6 4	Calculating and Characterizing Radiation Dose	52
6 5	Conducting an Uncertainty Analysis	53
7 0	ERA	54
7 1	Use of Draft Watershed ERA in CRA	56
7 2	CRA Background, SCM, and DQOs	57
7 2 1	Environmental Setting	57
7 2 2	SCM	57
7 2 3	Ecological Risk Management Goals and Assessment Endpoints	60
7 2 4	DQOs	61
7 2 5	Data Types and Adequacy	63
7 2 6	Ecological PRGs	64
7 3	Sitewide ECOC Identification Process	65
7 4	Risk Analysis Process	67
7 4 1	EUs	67
7 4 2	Risk Analysis Process for Non-PMJM Receptors	68
7 4 3	Risk Analysis Process for PMJM Receptor	70
7 4 4	Ecological Risk Characterization and Uncertainty	70
8 0	CRA REPORT ORGANIZATION	74
8 1	Schedule	75
9 0	REFERENCES	77

LIST OF TABLES

Table 4 1 CRA Exposure Factors for the Onsite WRW Receptor . 17
Table 4 2 CRA Exposure Factors for the WRV Receptor 18
Table 4 3 RFETS EU Areas 25
Table 4 4 Time-Weighted Average Activity Areas for WRWs 26
Table 4 5 Data Aggregation for the CRA 29
Table 4 6 Rationale for Selecting COCs 34
Table 4 7 Intake Equations for the WRW 37
Table 4 8 Intake Equations for the WRV 38
Table 5 1 Carcinogen Groups 40
Table 5 2 Nonradiological Toxicity Constants 41
Table 5 3 Radiological Toxicity Constants 47
Table 7 1 Representative Species for the ERA 61
Table 8 1 Completion Schedule for the Draft CRA 75

LIST OF FIGURES

Figure 1 1 CRA Process 4
Figure 2 1 Human Health Site Conceptual Model 6
Figure 4 1 Human Health Exposure Units 21
Figure 4 2 Exposure Units with IHSSs 23
Figure 4 3 Exposure Units with PACs 24
Figure 4 4 EU/AOC COC Selection Process 30
Figure 7 1 Sequence of Activities for the ERA 55
Figure 7 2 Ecological SCM 59
Figure 7 3 Sitewide ECOC Screening Process .66
Figure 7 4 CRA Risk Analysis Process for the Non-PMJM Receptor 69
Figure 7 5 CRA Risk Analysis Process for the PMJM Receptor. 72
Figure 7 6 Preble's Meadow Jumping Mouse Habitat with Exposure Units 73

APPENDICES

Appendix A –Screening Level Preliminary Remediation Goals

ACRONYMS

95UCL	upper confidence limit at a 95 percent level
AL	action level
ALF	Action Levels and Standards Framework for Surface Water, Ground Water, and Soils
AOC	Area of Concern
AWQC	Ambient Water Quality Criteria
BAF	bioaccumulation factor
BZ	Buffer Zone
CAD/ROD	Corrective Action Decision/Record of Decision
CAS	Chemical Abstract Service
CDPHE	Colorado Department of Public Health and Environment
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CHWA	Colorado Hazardous Waste Act
cm^2	square centimeter
COC	contaminant of concern
COI	contaminant of interest
CRA	Comprehensive Risk Assessment
CRAVE	Carcinogenic Risk Assessment Verification Endeavor
CRQL	contract-required quantitation limit
CSF	cancer slope factor
DAD	dermally absorbed dose
DCF	dose conversion factor
DER	duplicate error ratio
DOE	U S Department of Energy
DQA	Data Quality Assessment
DQO	data quality objective
DRI	daily reference intake
ECOC	ecological contaminant of concern
EcoSSL	ecological soil screening level
Eh	reduction-oxidation potential
EPA	U S Environmental Protection Agency
EPC	exposure point concentration
ERA	ecological risk assessment
EU	exposure unit

ACRONYMS, cont

GIS	Geographic Information System
HEAST	Health Effects Assessment Summary Tables
HHRA	human health risk assessment
HI	hazard index
HQ	hazard quotient
IA	Industrial Area
IASAP	Industrial Area Sampling and Analysis Plan
ICRP	International Commission on Radiological Protection
IHSS	Individual Hazardous Substance Site
IRIS	Integrated Risk Information System
kg	kilogram
kg/mg	kilograms per milligram
L/1,000 cm^3	liters per 1,000 cubic centimeters
L/day	liters per day
LHSU	lower hydrostratigraphic unit
LOAEL	lowest observed adverse effect level
m^2	square meter
m^3/day	cubic meters per day
MARSSIM	Multi-Agency Radiological Survey and Site Investigation Manual
MDL	method detection limit
mg/cm^2	milligrams per square centimeter
mg/kg	milligrams per kilogram
mrem	millirem
mrem/pCi	millirems per picocurie
mrem/pCi/g	millirems per picocurie per gram
NCRP	National Council on Radiation Protection and Measurement
NOAEL	no observed adverse effect level
NRC	Nuclear Regulatory Commission
NCEA	National Center for Environmental Assessment
ORNL	Oak Ridge National Laboratory

6

ACRONYMS, cont

OU	Operable Unit
PAC	Potential Area of Concern
PARCC	precision, accuracy, representativeness, completeness, and comparability
PCB	polychlorinated biphenyl
pCi	picocurie
pCi/g	picocuries per gram
pCi/L	picocuries per liter
PCOC	potential contaminant of concern
pH	hydrogen ion activity
PMJM	Preble's meadow jumping mouse
PQL	practical quantitation limit
PRG	preliminary remediation goal
RCRA	Resource Conservation and Recovery Act
RFCA	Rocky Flats Cleanup Agreement
RfD	reference dose
RFETS or Site	Rocky Flats Environmental Technology Site
RFI/RI	RCRA Facility Investigation/Remedial Investigation
RI/FS	Remedial Investigation/Feasibility Study
RL	reporting limit
RMA	Rocky Mountain Arsenal
RME	reasonable maximum exposure
ROC	receptor of concern
RPD	relative percent difference
RSAL	radionuclide soil action level
SAP	Sampling and Analysis Plan
SCM	Site Conceptual Model
SCMTM	Sitewide Conceptual Model Technical Memorandum
SMDP	scientific management decision point
SQV	sediment quality value
TSS	total suspended solids
UBC	Under Building Contamination

ACRONYMS, cont

UHSU	upper hydrostratigraphic unit
UL	upper limit daily nutrient intake
USFWS	U S Fish and Wildlife Service
V&V	verification and validation
WRV	wildlife refuge visitor
WRW	wildlife refuge worker
yr/pCi/g	years per picocurie per gram

1.0 INTRODUCTION

This document was prepared under Task 8, Prepare the Comprehensive Risk Assessment (CRA) Work Plan, of the Final Work Plan for the Development of the Remedial Investigation and Feasibility Study (RI/FS) Report (DOE 2002a) This document describes the scope, activities, and methodology for the Draft CRA The Draft CRA is referred to hereafter as the CRA The purpose of the CRA is to assess human health and ecological risks[1] posed by chemicals, metals, and radionuclides remaining at the Rocky Flats Environmental Technology Site (RFETS or Site) following accelerated actions The CRA will support the Draft RI/FS Detailed Analysis of Alternatives, Proposed Plan, and Corrective Action Decision/Record of Decision (CAD/ROD) for the Site

The tasks associated with this Methodology have evolved since the publication of the RI/FS Work Plan Task 8 of the work plan identifies 10 items that will be included in the CRA Work Plan and Methodology

1 Data quality objectives (DQOs),
2 Site Conceptual Model (SCM), including exposure scenarios, exposure pathways, and receptors,
3 Final list of contaminants of concern (COCs) following statistical evaluation and preliminary screening,
4 Reasonably foreseeable anticipated land use and use restrictions for the Site,
5 Background concentrations for COCs,
6 Established detection limits for COCs,
7 COC physical and chemical characteristics,
8 Methods for conducting the exposure assessment, toxicity assessment, and risk characterization,
9 Fate and transport models used to predict exposure point concentrations (EPCs), and
10 Preliminary remediation goals (PRGs) for surface soil, sediments, and groundwater from a human health and ecological perspective

Items 1, 2, 4, 8, and 10 are addressed directly in this Methodology For item 10, PRGs that have not been included in Rocky Flats Cleanup Agreement (RFCA) will be referred to as "screening level PRGs" to distinguish them from those that have been reviewed for inclusion in RFCA Items 3, 5, and 7 will be completed using methods discussed herein and reported in the CRA Item 6 was included in the Industrial Area (IA) and Buffer Zone (BZ) Sampling and Analysis Plans (SAPs) (DOE 2001, 2002b) Item 9 is discussed below in general and will be presented in depth in a separate groundwater modeling report Ecological PRGs will be developed and incorporated into Appendix N of Appendix 3 of the RFCA (DOE et al 1996 [as modified]) Other screening levels developed specifically for the CRA will be included in this Methodology

[1] In this document the term 'risk' will be used to refer to the combined "lifetime excess cancer risk" and noncarcinogenic health effects assessed with the hazard index (HI) for humans, and the calculated HI for ecological receptors

1.1 CRA Scope

Scope: The CRA will quantify and report risks posed by residual contamination at the Site to human and ecological receptors after accelerated actions

RFCA adopted an accelerated action cleanup approach to expedite remedial work and maximize early risk reduction at the Site, as described in RFCA paragraph 79 (DOE et al 1996) The CRA will be conducted in a progressive approach as accelerated actions are completed and data on the nature and extent of contamination are collected during the Sitewide RI/FS effort After accelerated actions, the need for further actions, if any, will be analyzed in the Draft RI/FS, hereafter referred to as the RI/FS Risks to human and ecological receptors posed by residual contamination at the Site will be quantified and evaluated in the CRA The CRA will be included in the RI/FS Report

A primary task associated with the CRA is the development of the Final CRA Work Plan and Methodology, hereafter referred to as the CRA Methodology This CRA Methodology presents the approach and methods to be used in the CRA and documents the SCM, exposure scenarios, exposure factors, toxicity assessment, and risk characterization The CRA Methodology is a major revision to and supersedes the previously circulated Draft Methodology (DOE 2000) This revision was required due to the change of the reasonably anticipated future use of RFETS as a wildlife refuge as designated by the Rocky Flats National Wildlife Refuge Act of 2001. This designation means that it is unlikely that RFETS would be used for limited industrial, unrestricted open space, or onsite residential uses

The CRA will assess all areas within the RFETS boundary For Operable Unit (OU) 3, Offsite Areas, a risk assessment was performed (DOE 1996a) and a CAD/ROD was issued (DOE 1997) The OU 3 risk assessment will be reviewed and summarized in the CRA However, OU 3 will not be reassessed unless the onsite assessment indicates circumstances that could alter the conclusions of the earlier OU 3 assessment Information that will be evaluated in this regard includes surface water and air monitoring data collected at the Site boundary, and new soil and surface water data acquired during accelerated actions Areas to be addressed within the RFETS boundary include areas containing existing or former OU designations While CAD/RODs have been issued for some of these OUs (OU 1, OU 11, OU 15, and OU 16), these areas are included to simplify the analysis process and enable a CRA for each designated exposure unit (EU) within the RFETS boundary

1.2 Technical Approach

The primary tasks required to complete the CRA, and their interrelationships, are detailed in this section Figure 1 1 depicts the overall technical approach and sequence of tasks, including the evaluation of additional data if required

Primary tasks include the following

- Generate the SCMs for both human health and ecological assessments with all defined exposure pathways, receptors, and scenarios,
- Identify exposure factors,
- Develop EUs, and
- Further refine PRGs and develop screening-level PRGs for the CRA.

The human health risk assessment (HHRA) and ecological risk assessment (ERA) will be conducted in parallel The CRA will assess residual contamination all available data including historical samples, monitoring data, and characterization and post-cleanup confirmation sampling results

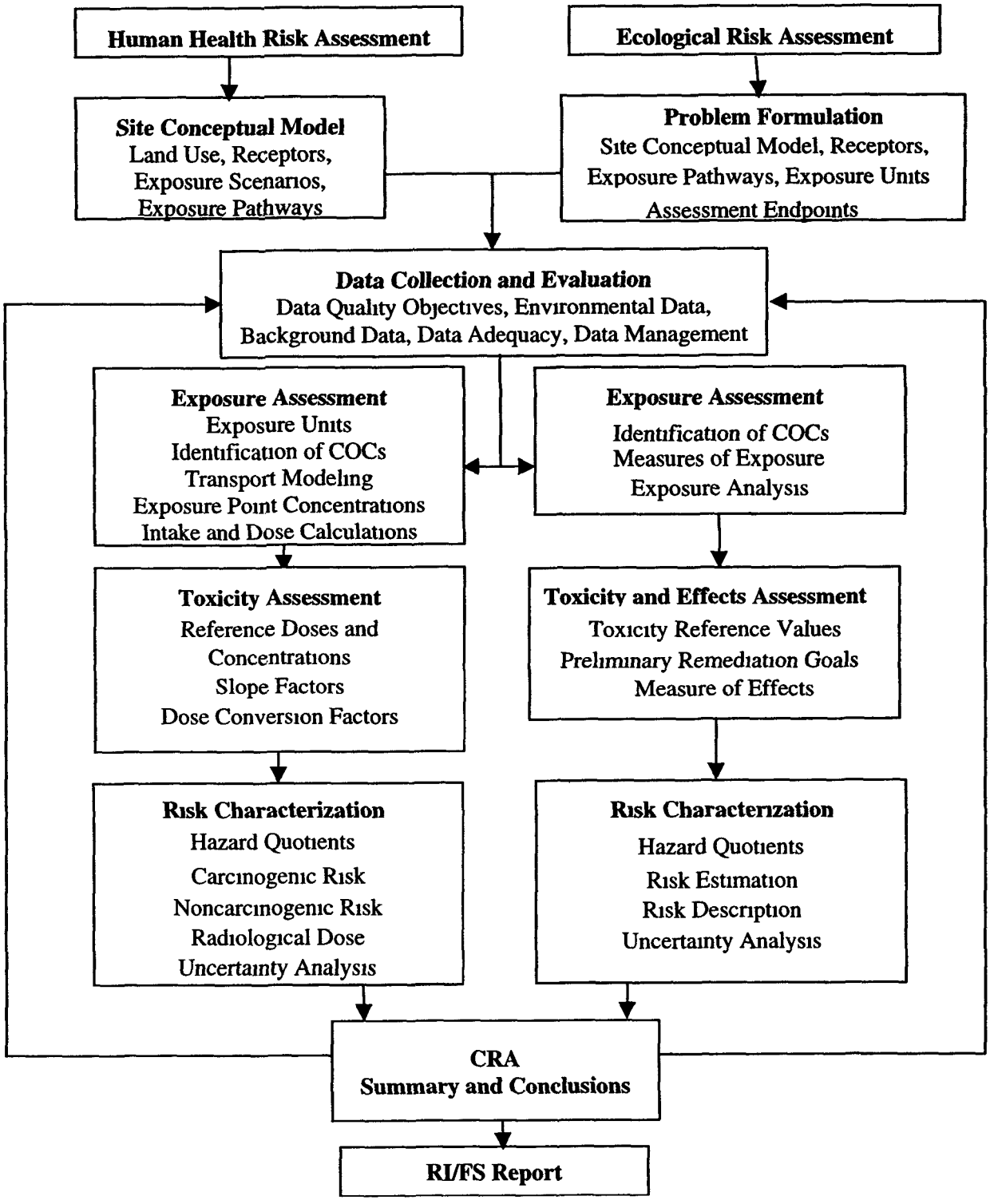
2.0 HUMAN HEALTH SCM

Action: Develop a SCM of receptors, exposure scenarios, and exposure pathways to guide the CRA process

The reasonably anticipated future land use for RFETS is a wildlife refuge The U S Department of Energy (DOE) will be responsible for stewardship activities, such as monitoring and maintenance, within those areas associated with a Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) remedy, as appropriate Refuge workers are assumed to be present on site for most of the year and engaged in refuge maintenance and ecological work activities A Comprehensive Conservation Plan is under development by the U S Fish and Wildlife Service (USFWS) (anticipated completion December 2004), in consultation with the Stakeholders Specific refuge activities will be determined by this plan

An exposure pathway describes a specific environmental route by which an individual receptor could be exposed to contaminants present at or originating from a site After the primary source(s) and release mechanisms are identified for the Site, the resulting secondary sources and secondary release mechanisms are identified and described Subsequent sources and release mechanisms are identified until the exposure pathways for each contaminant are fully delineated A complete exposure pathway includes five necessary elements source, mechanism of release, transport medium, exposure point, and intake route If any of these elements are missing, the pathway is incomplete

Figure 1.1 CRA Process



Exposure pathways and exposure routes in the SCM have been categorized as significant (S), insignificant (I), or incomplete (IC) using best professional judgment in consultation with the U S Environmental Protection Agency (EPA), Colorado Department of Public Health and Environment (CDPHE), and USFWS All such judgment will be supported by a thorough analysis of the available evidence The rationale and justification for the classification of all exposure pathways will be included in the CRA Report Significant and insignificant exposure pathways are complete exposure pathways Significant exposure pathways contribute the major portion of risk or dose An insignificant pathway is complete but will not contribute significantly to the total risk or dose An incomplete exposure pathway is missing one or more of the five elements necessary for a complete exposure pathway With an incomplete pathway, there will be no exposure, and the pathway will not contribute any risk or dose All significant exposure pathways will be quantitatively assessed at RFETS, while insignificant and incomplete exposure pathways will be qualitatively addressed

The comprehensive human health SCM, including all potentially viable exposure scenarios and pathways, is presented on Figure 2 1 Receptors in the SCM are described in detail below Exposure factors for each significant pathway are presented in Section 4 0

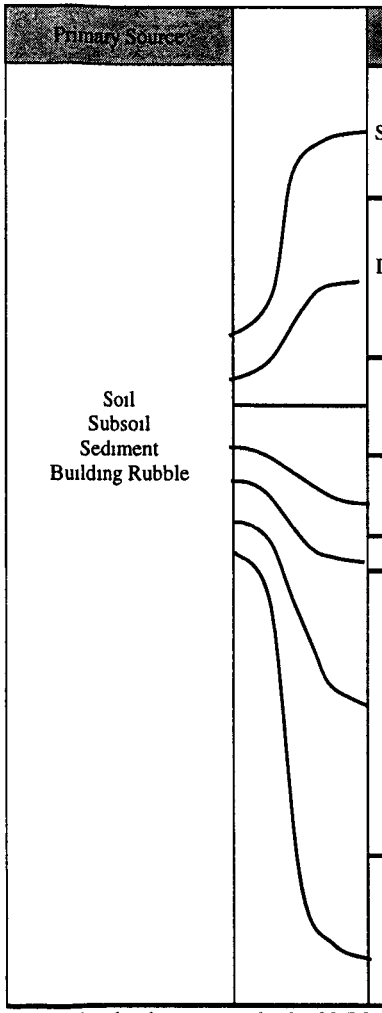
2.1 Receptors

Two types of receptors are associated with the wildlife refuge land use the wildlife refuge worker (WRW) and the wildlife refuge visitor (WRV) These scenarios are evaluated in the SCM and will be assessed in the CRA It is assumed that the WRW is exposed to outdoor contaminants for an average of one-half the workday Current planning by USFWS does not include year-round offices or an onsite visitor center A seasonally staffed visitor contact station may be built on the western side of the Site (USFWS 2003) If an office/visitor center was built on Site, there could be exposures to contaminants transported into the building for an average of one-half the workday for the WRW This potential exposure for the WRW will be assessed in each EU The WRV will have very limited exposures to indoor contaminants Primary exposures will be to outdoor contaminants Therefore, indoor exposures will not be assessed for the WRV

Risks to the offsite resident were assessed in the OU 3 Resource Conservation and Recovery Act (RCRA) Facility Investigation/Remedial Investigation (RFI/RI) Report performed in 1996 (DOE 1996a) Monitoring at the Site boundaries since completion of the RFI/RI indicates that there have been no releases from the Site that would alter the conclusions of the 1996 assessment Unless the onsite assessment indicates circumstances that could alter the conclusions of the 1996 OU 3 assessment, risks to the offsite resident will not be assessed Risks to an offsite receptor due to air transport are assessed in the annual National Emission Standards for Hazardous Air Pollutants Report for Radionuclides and the Annual Dose Assessment Report The onsite resident will not be assessed because residential use is not a reasonably anticipated land use

Ecological receptors will be identified and assessed in appropriate habitats EUs for ecological receptors are discussed in Section 7 0 Key ecological receptors have been selected to adequately represent the local ecological community and quantify the range of potential impacts

Figure 2.1 Human Health Site Conceptual Model



Primary Source	Primary Release Mechanism	Affected Media	Secondary Release Mechanism	Affected Media	Pathway Number	Validity Being Worked Exposure Pathways	Validity Being Worked Exposure Pathways
Soil Subsoil Sediment Building Rubble	Stormwater Runoff (S)	Surface Water Streams / Seeps	Direct Contact		S-1	Oral (I) Dermal (I)	Oral (I) Dermal (I)
			Biotic Uptake	Fish	S 2	Oral (IC)	Oral (IC)
			Ingestion	Deer/Grazing Animals	S-3	Oral (IC)	Oral (I)
	Infiltration Percolation (I)	UHSU Groundwater	Percolation	LHSU Groundwater	I-1	Oral (IC) Dermal (IC)	Oral (IC) Dermal (IC)
			Domestic Use		I-2	Oral (IC) Dermal (IC)	Oral (IC) Dermal (IC)
			Surface water		I-3	Oral (I) Dermal (I)	Oral (I) Dermal (I)
	Volatilization (V)	Groundwater Subsurface Soil	Volatilization	Indoor Air	V-1	Inhalation (I)	Inhalation (IC)
				Outdoor Air	V 2	Inhalation (I)	Inhalation (I)
		Surface Water	Volatilization	Outdoor Air	V 3	Inhalation (I)	Inhalation (I)
	Resuspension (R)	Airborne Particulates		Indoor Air	R-1	Inhalation (S)	Inhalation (IC)
				Outdoor Air	R-2	Inhalation (S)	Inhalation (S)
			Deposition	Deer/Grazing Animals	R-3	Oral (IC)	Oral (I)
	Plant Uptake (P)	Vegetation	Ingestion	Deer/Grazing Animals	P-1	Oral (IC)	Oral (I)
	Direct Contact (D)	Surface Soil (0 to 0 5 foot)[a]			D-1	Oral (S) Dermal (S[b])	Oral (S) Dermal (S[c])
		Subsurface Soil (0 5 to 8 feet)			D-2	Oral (S) Dermal (S[b])	Oral (IC) Dermal (IC)
		Subsurface Soil (Below 8 feet)			D-3	Oral (IC) Dermal (IC)	Oral (IC) Dermal (IC)
		Sediment[a]			D-4	Oral (S) Dermal (S[b])	Oral (S[b]) Dermal (S[b])
		Building Rubble			D-5	Oral (IC) Dermal (IC)	Oral (IC) Dermal (IC)
	Radioactive Decay (E)	Surface Soil			E-1	External Irradiation (S)	External Irradiation (S)
		Subsurface Soil			E-2	External Irradiation (I)	External Irradiation (I)
		Sediment			E 3	External Irradiation (S)	External Irradiation (I)
		Building Rubble			E-4	External Irradiation (I)	External Irradiation (I)

a Surface soil and sediments to a depth of 0 5 foot will be combined for the exposure assessment

b Dermal exposures will be assessed for organic COCs only

Key to Exposure Pathways
- S Significant
- I - Insignificant
- IC - Incomplete

2.2 Human Health Exposure Scenarios

The following exposure scenarios define the exposure pathways and assumptions for the WRW and WRV Insignificant and incomplete exposure pathways are also defined and discussed Justification for the classifications of exposure pathways will be included in the CRA If preliminary calculations or information suggest that a pathway is significant, the classification will be changed

2.2.1 WRW Exposure Scenario

The WRW scenario for the CRA is consistent with the WRW Scenario used for development of RFETS radionuclide soil action levels (RSALs) (EPA et al 2002) (Section 4 1 2) The WRW will be assessed in an indoor office scenario for an average of 50 percent of each day during a standard workweek of five days per week for all EUs The remaining 50 percent of the time will be spent outdoors on the Site This receptor will be exposed to residual contaminants in the IA, as well as all other onsite locations The WRW will conduct fieldwork that will result in limited exposure to contaminated soil, subsoil, sediment, and surface water RFCA Attachment 5, Figure 1 (DOE et al 1996 [as modified]), shows an area in the center of the Site that may be subject to institutional controls While DOE may retain administrative jurisdiction over some areas of the Site, the reasonably anticipated future land use for the Site is a wildlife refuge Therefore, this area will be assessed using the WRW receptor

Monitoring, maintenance, and other long-term stewardship activities to implement and evaluate the continuing protectiveness of the comprehensive final remedy will occur on Site The exposure parameters and pathways due to these activities are contained within the WRW scenario It is assumed that exposures due to monitoring, maintenance, and other stewardship activities will be less than for the WRW scenario This is because environmental workers will work to appropriate Site Health and Safety Plans (as Site workers do currently) and appropriate protective equipment will be used Consequently, these individuals will not be exposed to contaminants at any higher concentrations than those to which the WRW is exposed, and the exposure frequency will be low Therefore, the WRW scenario provides an upper bound for risks due to these activities, and a specific "stewardship receptor" will not be assessed in the CRA

Complete Exposure Pathways for the WRW

Potentially complete exposure pathways from which exposures are expected for the WRW include

- Ingestion of and dermal exposures to surface soil/sediments, subsurface soil, and surface water,
- Inhalation of volatiles and particulates, and
- External exposure to beta and gamma radiation from radionuclides present in soil, subsurface soil, sediment, and building rubble

Complete and Significant Exposure Pathways for the WRW

The exposure pathways for the WRW that are expected to be both complete and have the possibility of contributing significant risk are

- Inhalation of surface, sediment, and subsurface soil particulates,
- Ingestion of surface soil and subsurface soil/sediments,
- Dermal exposure to surface/sediments and subsurface soil, and
- External irradiation exposure from surface soil, sediments, and subsurface soil

Complete but Insignificant Pathways for the WRW

Best professional judgment has been used to designate exposure pathways that are considered complete, but are not anticipated to contribute significantly to Site risks to the WRW This is generally due to a variety of factors that lead to low intakes The rationale and justification for the classification of all exposure pathways will be included in the CRA Report The following pathways are considered insignificant

- Ingestion of surface water,
- Dermal exposure to surface water,
- Inhalation of volatiles from groundwater,
- Inhalation of volatiles from surface soil and subsurface soil, and
- External irradiation exposure from subsurface soil and building rubble

Incomplete Exposure Pathways for the WRW

Best professional judgment has been used to designate exposure pathways that are considered incomplete Incomplete pathways imply that exposures are not anticipated and consequently will not contribute to Site risks to the WRW The rationale and justification for the classification of all exposure pathways will be included in the CRA Report The following pathways are considered incomplete

- Ingestion of fish and/or deer/grazing animals from the Site,
- Ingestion of groundwater,
- Ingestion of homegrown produce, and
- Ingestion of building rubble

2.2.2 WRV Exposure Scenario

The WRV scenario is based on the open space scenario used in the RSAL Report (EPA et al 2002) The WRV includes both a child and adult who visit the Site 100 days/year for 2 5 hours/day, for a total of 250 hours/year The remaining time is spent off site Outdoor recreational activities will primarily be on and near established hiking trails Hunting may be allowed on a very limited basis, possibly by lottery It is assumed that this receptor may be exposed to residual contaminants It is also assumed that the WRV will not conduct activities resulting in significant exposure to subsurface soil and surface water

Complete Exposure Pathways for the WRV

Potentially complete exposure pathways from which exposures are expected for the WRV include

- Ingestion of and dermal exposures to surface soil/sediments, subsurface soil, and surface water,
- Ingestion of deer and/or grazing animals,
- Inhalation of volatiles and particulates, and
- External exposure to beta and gamma radiation from radionuclides present in soil, subsurface soil, sediment, and building rubble

Complete and Significant Exposure Pathways for the WRV

The exposure pathways for the WRV that are considered both complete and have the possibility of contributing significant risk are

- Inhalation of surface soil/sediment particulates,
- Ingestion of surface soil/sediment,
- Dermal exposure to surface soil/sediment, and
- External irradiation exposure from surface soil/sediment

Complete but Insignificant Exposure Pathways for the WRV

Best professional judgment has been used to designate exposure pathways that are considered complete, but are not anticipated to contribute significantly to Site risks to the WRV An insignificant designation is generally due to a variety of factors that lead to low intakes The rationale and justification for the classification of all exposure pathways will be included in the CRA Report The following pathways are considered insignificant for the WRV

- Ingestion of surface water,
- Dermal exposure to surface water,
- Ingestion of deer and/or grazing animals,
- Inhalation of outdoor air volatiles from surface water and groundwater,
- Inhalation of outdoor air volatiles from surface and subsurface soil,
- Inhalation of indoor air on Site, and
- External irradiation exposure from subsurface soil and building rubble

Incomplete Exposure Pathways for the WRV

Best professional judgment has been used to designate exposure pathways that are considered incomplete The rationale and justification for the classification of all exposure pathways will be included in the CRA Report The following pathways are not anticipated to result in exposures, will not contribute to Site risks, and are considered incomplete for the WRV

- Ingestion of groundwater, and
- Ingestion of building rubble

17

3.0 DATA COLLECTION AND EVALUATION

Actions: Identify data needs and data sources, assemble data, and evaluate data quality and adequacy

Data evaluation and aggregation will be performed on an EU and Area of Concern (AOC) basis for the HHRA The EU and AOC are defined in Section 4 2 Methods are described below The DQO process specifies project decisions and techniques necessary to generate quality data and make associated conclusions (EPA 2000a) The DQO process will be used to

- Define stated objectives,
- Define appropriate data collection methods,
- Establish necessary data types,
- Conduct data aggregation, and
- Specify acceptable levels of data quantity and quality necessary to support the risk assessment process

Nature and extent data that have been collected historically at RFETS, and also progressively during RI/FS investigations and accelerated actions, will be identified and assembled Verification and Data Quality Assessment (DQA) procedures will be used to verify the quality and comparability of collected data Data that are no longer relevant due to accelerated actions will be filtered out of the data set COCs will be identified to support a comprehensive HHRA and ERA Risks will be evaluated and quantified for receptors by exposure scenarios and pathways for established EUs and AOCs, and summarized accordingly

Site data will be used to evaluate sources of contamination and determine contaminant distributions Exposure parameters, such as inhalation and ingestion rate, exposure frequency, and exposure duration, have been determined for identified Site-specific receptors Toxicity data will be collected to identify or derive dose limits to human and ecological receptors Physical and chemical parameters for all viable COCs will also be collected, as necessary, to support a complete toxicity assessment, assessment of impacts to receptors, and determination of environmental fate and transport mechanisms Radiological data for pertinent radionuclides, including plutonium-239, americium-241, uranium-235, and uranium-238, will be collected to determine recent dose conversion factors and radiological emission data Ecological data will be collected from the ecological screening assessments for the BZ and IA, including receptor species, biological information, and Site habitat usage

3.1 HHRA DQOs

The CRA follows the EPA DQO process to ensure that the type, quantity, and quality of environmental data used in decision making are appropriate for the intended purpose (EPA 2000a) The DQO process consists of seven steps that specify project decisions, the data

18

quality required to support those decisions, specific data types needed, data collection requirements, and analytical techniques necessary to generate the specified data quality. During the first six steps of the DQO process, the planning team develops decision performance criteria (i e , DQOs) for the data collection design All decision rules need to be considered, as appropriate The final step of the process involves developing the data collection design based on the DQOs

3.1.1 Step 1: State the Problem

Human health risks from exposure to residual contaminants present in environmental media at RFETS must be quantified to determine whether end-state long-term land use is protective and within the range of acceptable risk The nature and extent of COCs must be adequately determined to quantify human health risks at RFETS

The problem is

> *"The risks to all reasonably expected human receptors exposed to residual contaminants present in environmental media following accelerated actions must be quantified in a technically sound and defensible manner "*

3.1.2 Step 2: Identify the Decision

The primary decision is

> *"Are risks to human receptors at RFETS following exposure to residual contamination acceptable based on the reasonably anticipated future land use?"*

Resolution of the following key secondary decisions will be required to ensure completion of the CRA

- Has a methodology been developed to adequately assess human health risks?
- Has a methodology been developed to adequately identify COCs?
- Is the CRA SCM adequate to define all viable exposure scenarios, exposure pathways, and receptors based on the reasonably anticipated future land use?
- Have all EUs and AOCs been adequately defined and established?
- Have the nature and extent of inorganic, organic, and radionuclide analytes within EUs been identified with adequate confidence, based on evaluation of Site process knowledge and analytical data?
- Have samples of adequate number and quality been collected within EUs and AOCs to perform the risk assessment?

3.1.3 Step 3: Identify the Inputs to the Decision

Available historical information, sampling data, and risk assessment requirements will be used to determine adequate sampling locations and densities for EUs and AOCs

The CRA DQA methodology (Section 3 1 5) will be applied to all data used in the CRA Data will be screened through the COC selection process as described in Section 4 4 All data will also be screened using professional judgment to ensure it meets risk assessment needs

The rationale and justification will be included in the CRA Report All selected COCs will be used to calculate risks to receptors

3.1.4 Step 4: Define Study Boundaries

Study boundaries are used to define the spatial and temporal boundaries for data collection in support of the decision to quantify risk to receptors Environmental media analyte data will be assessed for surface soil and sediments to a depth of 6 inches, and for subsurface soil from 6 inches to 8 feet Existing environmental media data will be used when possible and additional sampling will be conducted if determined to be necessary Sufficient samples will be collected to statistically evaluate the data, identify COCs, and quantify risk to receptors These results will be used in the CRA

The assessment will be confined to the area within the RFETS boundary unless the onsite assessment indicates circumstances that could alter the conclusions of the assessment performed earlier for OU 3, Offsite Areas (DOE 1996a)

EUs will be established using a tiered approach Functional EUs for the WRW and WRV receptors have been established based on watersheds, known patterns of contamination, and expected activity patterns Known Individual Hazardous Substance Sites (IHSSs), Potential Areas of Concern (PACs), and Under Building Contamination (UBC) Sites of special interest will be grouped into AOCs based on PRG screening (Section 4 2) Analyte data will be aggregated at both the EU and AOC levels to quantify risk to human receptors

Statistical evaluation of environmental data will include standard descriptive calculations, precision, accuracy, representativness, completeness, and comparability (PARCC) parameter analyses, distribution testing, population testing of Site data relative to background, nonparametric tests, and probabilistic resampling techniques, such as Bootstrapping and power calculations

Data from environmental media will not be collected to support exposure pathways designated as insignificant

3.1.5 Step 5: Identify the Data Adequacy Decision Rules

This section presents the decision rules to determine data adequacy for the CRA The nature and extent of organics, inorganics, and radionuclides must be determined with sufficient certainty to permit adequate quantification of statistical analyses and quantification of risk to receptors Data adequacy criteria must, therefore, be met or additional sampling and analysis will have to be performed

The following decision rules will be used to determine whether analyte data are adequate to support statistical and risk-based calculations

Data Sufficiency Assessment

The sample data collected for each COC in an EU or AOC will be used to determine an upper confidence limit at a 95 percent level (95UCL) of statistical confidence for the COC The 95UCL will then be used as the exposure point concentration (EPC) for the COC in the risk assessment However, 95UCLs are only valid if sufficient numbers of sample data are available While it is possible to calculate a 95UCL with only two or three samples, its

validity is questionable Therefore, it is necessary to determine how many samples are required to calculate a 95UCL for each COC

Sampling power will be evaluated to statistically determine whether sufficient samples were collected to adequately determine COCs and calculate 95UCLs within the EUs and AOCs to support risk assessment The decision to be made is

> *"Given the estimate of the mean analyte concentration, the observed variance, and the calculated 95UCL, is the number of samples collected adequate to identify an exceedance of PRGs for the WRW (at risk = 10^{-6} or hazard quotient [HQ] = 0 1) with an alpha error of 0 1 and a beta error of 0 2?"*

All potential contaminants of concern (PCOCs) will be evaluated

The CRA will use the nonparametric method as presented in the Multi-Agency Radiological Survey and Site Investigation Manual (MARSSIM) Report §5 5 2 3 (NRC 1997) for determining data sufficiency

Estimates of the averages and variances will be derived as required to calculate the 95UCLs Relative errors will be derived from the difference between the PRG and the mean and 95UCL Relative errors derived from averages and 95UCLs will bound sampling errors due to inherent heterogeneity of analytes in environmental media to predict the number of samples required

The results for all PCOCs detected in each EU and AOC will be summarized The results of the data sufficiency calculations for each area will be evaluated collectively At this point, other information on historical releases, Site usage, and process knowledge will also be reviewed A decision will be made whether the data are sufficient or insufficient for the CRA Results will be presented to the regulatory agencies for their concurrence

PARCC Parameter Assessment

Data quality and adequacy will also be assessed using a standard PARCC parameter analysis (EPA 2000b) for all data in each environmental media as described below

Precision

For nonradiological contaminants, if the relative percent difference (RPD) between the target and duplicate, at concentrations five times the reporting limit (RL), is less than 35 percent for solids and 20 percent for liquids, the overall precision of the contaminant concentration is adequate Otherwise, the magnitude of the imprecision must be addressed in the CRA and/or additional samples may be required (EPA 2000b)

For radiological contaminants, if the duplicate error ratio (DER) is less than 1 96, the overall precision of the contaminant concentration is adequate Otherwise, the magnitude of the imprecision must be addressed in the CRA and/or additional samples may be required (EPA 2000b)

Accuracy

If overall accuracy complies with EPA methodology SW-846 (EPA 1994), as verified through formal verification and validation (V&V) (EPA 2000b) of the results, then results

21

may be used in the CRA without qualification. Otherwise, the magnitude of the inaccuracy(s) must be addressed in the CRA and/or additional samples may be required

Representativeness

Prerequisites to the decision criteria include an adequate number of valid sample results as stipulated in the Completeness section, and sample acquisition and analysis under an approved Quality Program as follows

- If sampling locations are spatially distributed such that contaminant randomness and bias considerations are addressed based on the site-specific history, then sample results are representative Otherwise, the results must be qualified and/or additional samples collected
- If samples were analyzed by EPA method SW-846 and results were documented accordingly, as quality records, the sample results are representative of contaminant concentrations Otherwise, results (the CRA) must be qualified and/or additional samples collected

Completeness

Completeness may be determined using either of the following determinations

1. comparison of actual samples (collected) with the planned number of samples, where the plan was an approved CERCLA-based SAP, or

2 determination of sample power through an appropriate statistical model, such as EPA QA/G-4 (EPA 2000a), EPA QA/G-9 (EPA 2000b), or MARSSIM (NRC 1997)

These two options are described as follows

1 Planned vs Actual Number of Samples

- If the overall completeness of the data in the EU of interest is at least 95 percent (for a given contaminant), the data are adequate Otherwise, the data (CRA) must be qualified and/or additional samples collected

2 Sample Power Calculations

- If enough samples were collected to attain 95 percent confidence in decisions (i e , the contaminant concentration of interest is less than its associated RFCA action level [AL]) within the given EU, the number of samples is adequate Otherwise, the data (CRA) must be qualified and/or additional samples collected

Comparability

Sample collection and analysis methods will be reviewed for comparability Similarities and differences between the sample collection and analysis methods will be documented Decisions on comparability will be made in consultation with the regulatory agencies If chemical and radiological results are comparable within the aggregated (CRA) data set based on defined matrices and standardized units of measure (e g , picocuries per gram [pCi/g] and milligrams per kilogram [mg/kg]), the data are adequate for use in the CRA Otherwise, the results must be converted or normalized, the CRA qualified, and/or additional samples collected (EPA 2000b)

22

3.1.6 Step 6: Specify Tolerable Limits on Decision Errors

Sources of uncertainties in the risk assessments will be identified, minimized, and documented in the CRA This may include use of upper-bound numbers or ranges of values, as applicable, for various parameters considered, concentration term estimates, contaminant transport, data distribution assumptions, and EU use assumptions

Where alpha and beta errors are applicable in statistical hypothesis testing, these errors will also be documented Alpha error will not exceed 10 percent in sample power calculations, whereas beta error will not exceed 20 percent in sample power calculations Relative errors will be determined based on the differences between the PRG for an analyte and the upper 95UCL or the estimate of the average analyte concentration (EPA 2002a)

3.1.7 Step 7: Optimize the Design

Based on the iterative nature of the DQO process, any decision that is not consistent with project goals will result in a reinitiation of the DQO process If determination of the nature and extent of analytes is found to be inadequate, further sampling will be initiated If sampling power is determined to be inadequate for any given scenario and set of analyte data, more samples will be collected and the sampling power will be recalculated

4.0 HHRA EXPOSURE ASSESSMENT

> **Actions:** Identify potential land use and exposed populations, develop the SCM, exposure factors for each pathway, and EUs for data aggregation, identify COCs, determine whether transport modeling is necessary, estimate COC EPCs, and quantify intake to receptors

The CRA human health exposure assessment will quantitatively and qualitatively evaluate contact between human receptors and COCs The exposure assessment will estimate the total dose or intake for a receptor in an EU or AOC for a particular land use and exposure scenario The calculated dose is then combined with chemical-specific dose-response data to estimate risk (EPA 1992) The exposure assessment methods for the HHRA are described in detail in the following sections

4.1 Exposure Factors

This section presents the exposure factors for the HHRA

4.1.1 Exposure Pathway Assessment

Exposure pathways, the course a contaminant takes from the source to a receptor, are shown in the SCM (Figure 2 1) In the model, exposure pathways are designated as incomplete (IC), complete and significant (S), or complete and insignificant (I) as defined previously

Direct contact with surface soil, subsurface soil (less than 8 feet in depth), and sediments, the inhalation of airborne contaminants, and exposure to penetrating radiation are the primary exposure pathways of concern Contact with subsurface soil is considered for the WRW, but is limited in both exposure frequency and exposure duration Ingestion of and dermal contact

23

with surface water and volatilization of contaminants are considered insignificant pathways Ingestion of or dermal contact with groundwater are considered incomplete and will not be assessed Ingestion of or dermal contact with groundwater that daylights at seeps or streams are considered to be insignificant pathways Ingestion of animal tissue is incomplete for the WRW, but is considered insignificant for the WRV due to possible limited hunting activity All other exposure pathways are considered incomplete and will not be addressed, including ingestion of groundwater and/or fish

Inhalation Pathway

The inhalation pathway will be assessed for resuspension of airborne contaminants present in surface soil transported to human and ecological receptors The receptors will be assessed for this exposure pathway using the contaminant concentration in the soil and the mass loading variable developed for the RSALs The potential volatilization of contaminants from soil and shallow groundwater to receptor locations is considered an insignificant pathway Volatilization into office space will be evaluated for WRW offices Sitewide, if determined to be a significant pathway

Ingestion Pathway

The ingestion pathway will be assessed for direct ingestion of contaminants present in surface soil and sediments for the WRW and WRV receptors Direct ingestion of surface water will not be assessed for the WRW and WRV receptors Exposures to contaminants in groundwater in the upper hydrostratigraphic unit (UHSU) transported to surface water is currently considered insignificant A preliminary assessment will be performed and reported in the CRA to justify this decision Ingestion of deep aquifer groundwater will not be assessed as a viable exposure pathway

Runoff from contaminated soil to nearby surface water could result in direct ingestion of contaminated surface water by all receptors and contribute to possible contamination of aquatic species However, direct ingestion of surface water and contaminated fish collected from the area are considered insignificant and incomplete pathways, respectively, and will not be assessed Collection of meat from hunting activities and subsequent ingestion is also considered insignificant and will not be assessed

Dermal Exposure

Dermal exposure due to contact with contaminated soil and sediments will be assessed for the WRW and WRV receptors Dermal exposure to surface water will not be assessed for either receptor

External Exposure

External exposure will be assessed for both receptors to determine impacts to human receptors resulting from exposure to external penetrating radiation emanating from radionuclides present in contaminated environmental media and associated contamination

4.1.2 WRW Scenario Exposure Factors

The exposure factors for the WRW are presented in Table 4 1 Factors were taken from the RSALs Task 3 Report (EPA et al 2002) when available Dermal exposures were not included in the RSALs The sediment and subsurface pathways also were not assessed in the RSALs report

Table 4.1 CRA Exposure Factors for the Onsite WRW Receptor

Exposure Factor	Abbreviation	Units	Value	Source
Chemical concentration in medium	Cs	mg/kg/pCi/g	chemical-specific	
Adult body weight	BWa	kg	70	EPA 1991
Surface soil/sediment exposure frequency	EFwss	day/yr	230	EPA et al 2002
Surface-subsurface soil/sediment exposure frequency	EFwsub	day/yr	20	DOE 2003
Exposure duration	EDw	yr	18 7	EPA et al 2002
Exposure time	ETw	hr/day	8	EPA et al 2002
Exposure time fraction, outdoor	Eto_w	--	0 5	EPA et al 2002
Exposure time fraction, indoor	Eti_w	--	0.5	EPA et al 2002
Averaging time - noncarcinogenic	ATnc	day	6826	Calculated
Averaging time - carcinogenic	ATc	day	25550	Calculated
Soil/sediment ingestion rate	IRwss	mg/day	100	EPA et al 2002
Skin-soil adherence factor	AFw	mg/cm^2-event	0 12[a]	EPA 2001a
Event frequency	EVw	events/day	1	EPA 2001a
Skin surface area (exposed)	SAw	cm^2	3300[b]	EPA 2001a
Soil dermal absorption fraction	ABS	--	chemical-specific	EPA 2001a
Inhalation rate	IRaw	m^3/hr	1 3	EPA et al 2002
Dilution factor, indoor inhalation	DFi	--	0 7	EPA et al 2002
Mass loading, (PM10) for inhalation	MLF	kg/m^3	6 7E-08[c]	EPA et al 2002
Area correction factor	ACF	--	0 9	EPA et al 2002
Gamma shielding factor (1-Se) outdoor	GSFo	--	1	EPA et al 2002
Gamma shielding factor (1-Se)	GSFi	--	0 4	EPA et al 2002
Gamma exposure factor (annual) surface soil = (EFwss / 365 day/yr)	Te_A	--	0 7	Calculated
Gamma exposure factor (annual) subsurface soil = (EFwsub / 365 day/yr)	Te_As	--	0 05	Calculated
Gamma exposure factor (daily) outdoor = (Etw*Eto_w hr/day / 24 hr/day)	Te_Do	--	0 15	Calculated
Gamma exposure factor (daily) indoor = (8 hr/day / 24 hr/day)	Te_Di	--	0 15	Calculated
Conversion factor 1	CF1	kg/mg	0 000001	
Conversion factor 2	CF2	g/kg	1000	
Conversion factor 3	CF3	g/mg	0 001	

a The skin soil adherence factor is the geometric mean for farmers This value is recommended by CDPHE for use in the WRW PRGs

b The skin surface area value is the EPA default for commercial/industrial exposures and is the average of the 50th percentile for men and women >18 years old wearing a short-sleeved shirt, long pants, and shoes The value was recommended by CDPHE for use in the WRW PRGs

c The mass loading value is the 95th percentile of the estimated mass loading distribution estimated in the RSALs Task 3 Report (EPA et al 2002)

25

4.1.3 WRV Scenario Exposure Factors

Current plans for the wildlife refuge include public uses similar to open space usage previously developed for RFETS, with trails for wildlife observation, hiking, and biking (USFWS 2003) The exposure time and duration factors for the WRV receptor, presented in Table 4 2, are based on a survey conducted by Jefferson County of open space users (Jefferson County 1996) The values were first used in the open space PRG calculations for the Site and were adapted for the RSALs Report

Table 4.2 CRA Exposure Factors for the WRV Receptor

Exposure Factor	Abbreviation	Units	Value	Source
Concentration in medium	Cs	mg/kg / pCi/g	chemical-specific	
Adult body weight	BWa	kg	70	EPA 1991
Child body weight	BWc	kg	15	EPA 1991
Exposure frequency	EFv	day/yr	100	EPA et al 2002[a]
Exposure duration-adult	EDav	yr	24	EPA 1991
Exposure duration-child	EDcv	yr	6	EPA 1991
Exposure duration-total	EDt	yr	30	EPA 1991
Exposure time	ETv	hr/day	2 5	EPA et al 2002[b]
Adult averaging time - noncarcinogenic	ATancv	day	8760	Calculated
Child averaging time - noncarcinogenic	ATcncv	day	2190	Calculated
Averaging time - carcinogenic	ATc	day	25550	EPA 1991
Adult soil ingestion rate	SIRav	mg/day	50	EPA et al 2002
Child soil ingestion rate	SIRcv	mg/day	100	EPA et al 2002
Age-adjusted soil ingestion rate for non-radionuclides	SIRageav	mg-yr/kg-day	57	Calculated
Age-adjusted soil ingestion rate for radionuclides	SIRagav_r	mg/day	60	Calculated
Adult skin-soil adherence factor	AFav	mg/cm^2-event	0 07[c]	EPA 2001a
Child skin-soil adherence factor	AFcv	mg/cm^2-event	0 2[d]	EPA 2001a
Event frequency	EVv	events/day	1	EPA 2001a
Adult skin-surface area (exposed)	SAav	cm^2	5700[e]	EPA 2001a
Child skin-surface area (exposed)	SAcv	cm^2	2800[f]	EPA 2001a
Age-averaged surface area/adherence factor	SFSagav	mgyr/kg-event	361	EPA 2001a
Dermal absorption fraction	ABS	--	chemical-specific	EPA 2001a
Outdoor inhalation rate - adult	IRov	m^3/hr	2 4	EPA et al 2002
Outdoor inhalation rate - child	IRcov	m^3/hr	1 6	EPA et al 2002
Age-averaged inhalation factor (non-radionuclides)	IRagav	m^{3}yr/kgday	3 7	EPA et al 2002
Age-averaged inhalation rate (radionuclides)	Iragav_r	m^3/hr	2 2	EPA et al 2002
Mass loading, (PM10) for inhalation	MLF	kg/m^3	6 7 E-8[g]	EPA et al 2002
Area correction factor	ACF	--	0 9	EPA et al 2002
Gamma shielding factor (1-Se) outdoor	GSFo	--	1	EPA et al 2002
Gamma exposure factor (annual) = (EFv / 365 day/yr)	Te_Av	--	0 3	Calculated
Gamma exposure factor (daily) = (ETv hr/day / 24 hr/day)	Te_Dv	--	0 1	Calculated
Conversion factor 1	CF1	kg/mg	0 000001	

Exposure Factor	Abbreviation	Units	Value	Source
Conversion factor 2	CF2	g/kg	1000	
Conversion factor 3	CF3	g/mg	0 001	

a Value is the 95th percentile of visitation frequency for open space users (Jefferson County 1996)
b Value is the 50th percentile of time spent for open space users (Jefferson County 1996)
c The adult skin-soil adherence factor is the EPA residential default and the 50th percentile for gardeners This is the value recommended by CDPHE for use in the WRW PRGs
d The child skin-soil adherence factor is the EPA residential default and the 95th percentile for children playing in wet soil This is the value recommended by CDPHE for use in the open space user PRGs
e The adult skin-surface area value is the EPA default for residential exposures and the average of the 50th percentile for males and females >18 years old wearing short-sleeved shirts, shorts, and shoes The value was recommended by CDPHE for use in the WRW PRGs
f The child skin-surface area value is the EPA default for residential exposures and the average of the 50th percentile for males and females from <1 to <6 years old wearing short-sleeved shirts, shorts, and no shoes The value was recommended by CDPHE for use in the WRW PRGs
g The mass loading value is the 95th percentile of the estimated mass loading distribution estimated in the RSALs Task 3 Report (EPA et al 2002)

4.2 Functional EUs and AOCs

Sources of contamination will be determined using available Site data to assess the spatial and temporal distribution of all classes of contaminants This information will be used to support the selection of COCs and AOCs The AOCs will be identified and illustrated on Site maps, source terms will be defined, to the extent possible, with available information Significant data gaps for contaminant sources and distributions will also be identified and resolved

4.2.1 EU Development

Human health risks and health hazards will be assessed in three ways at RFETS

- An onsite WRW will be assessed based on exposure to COCs selected for each EU
- An onsite WRW will be assessed based on exposure to COCs selected for each AOC, as determined by the procedure discussed below
- An onsite WRV will be assessed based on exposure to COCs selected for each EU The same EUs will be used for the WRV as for the WRW assessment

The EUs for the WRW and WRV are illustrated on Figure 4 1 AOCs will be established to define those areas that represent distinct potential impacts to receptors from the perspective of source terms, observed COCs, nature and extent of contaminant transport, and spatial locations

As stated above, sources of contamination will be determined using Site data to assess the spatial and temporal distribution of all classes of contaminants This information will be used to support the selection of COCs Primary areas of contamination will be identified and depicted on Site maps to define AOCs Data sufficiency will be assessed

4.2.2 Defining and Assessing EUs

Risk assessments evaluate the long-term threats to human health and the environment An EU is the area over which long-term risks to the chosen receptors are assessed The EU is an embodiment of the exposure scenario and its size varies with the land use and receptor activities Recreational or open space EUs are generally large, depend on the recreational

27

activities envisioned for the site, and represent the area over which a receptor ranges during recreational activities The activities of a WRW are even more extensive and varied, and the area over which the worker will be exposed during a career is quite large

The RFETS EUs integrate the above factors and also

- Consider Site contaminant release patterns and distinct areas of contamination,
- Aggregate data on a watershed basis,
- Support future land use planning,
- Facilitate assessment of risk in functional areas, and
- Comply with RFCA/CERCLA requirements

The RFETS EUs represent long-term activity areas in which the WRW and WRV will be exposed to residual contamination The importance and relationship of the above items to long-term risks are discussed below

THIS TARGET SHEET REPRESENTS AN
OVER-SIZED MAP / PLATE FOR THIS DOCUMENT:
(Ref: 03-RF-01471; JLB-094-03)

Draft Final Comprehensive Risk Assessment Work Plan and Methodology

September 2003

Figure 4.1:

Human Health Exposure Units

File: W:\Projects\Fy2003\eco\eco.apr

May 30, 2003

CERCLA Administrative Record Document, SW-A-004835

U S DEPARTEMENT OF ENERGY
ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE

GOLDEN, COLORADO

29

Contaminant Release Patterns

Contaminant release patterns and known sources were incorporated in the delineation of the RFETS EUs, as shown on Figures 4 2 and 4 3 The objective is to assess areas with similar types of contamination on a collective basis For example

- The IA EU has the most IHSSs, PACs, and UBC sites and was the area most affected by industrial activities at the Site
- The Wind Blown Area EU includes surface soil affected by the 903 Pad release that is characterized by elevated plutonium and americium activities
- The Upper Walnut Drainage EU includes the A- and B-Series ponds, which have elevated levels of radionuclides in sediments
- The No Name Gulch Drainage EU encompasses the Present Landfill and downgradient areas
- The Lower Walnut Drainage EU stream sediments are affected by surface water flows from the ponds and erosion from the Wind Blown Area
- The Woman Drainage EU is affected by the 903 Pad, the Original Landfill, and other IHSSs and PACs
- The remaining four EUs are not significantly affected by releases from the Site

Watersheds

The EUs were designed on a watershed basis This was done to account for similar long-term fate and transport processes for residual contaminants in soil and sediments The major surface transport process for persistent contaminants in surface soil is overland flow and transport of eroded soil in surface water The EUs represent distinct areas affected by the potential transport of residual contamination from well-defined sources and activity areas for the WRW and WRV receptors based on similar landscapes and habitats

Future Land Use Planning

The EUs were designed to support future land use planning by assessing risks for areas aggregated by similar geography, ecology, and expected usage This will enable planners and managers to use the results of the CRA to determine areas of the Site to target for more intensive recreational development or other uses, such as ranger offices or a visitor center for the refuge

THIS TARGET SHEET REPRESENTS AN
OVER-SIZED MAP / PLATE FOR THIS DOCUMENT:
(Ref: 03-RF-01471; JLB-094-03)

Draft Final Comprehensive Risk Assessment Work Plan and Methodology

September 2003

Figure 4.2:

Exposure Units with IHSSs

File: W:\Projects\Fy2003\eco\eco.apr

May 29, 2003

CERCLA Administrative Record Document, SW-A-004835

U S DEPARTEMENT OF ENERGY
ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE

GOLDEN, COLORADO

31

THIS TARGET SHEET REPRESENTS AN
OVER-SIZED MAP / PLATE FOR THIS DOCUMENT:
(Ref: 03-RF-01471; JLB-094-03)

Draft Final Comprehensive Risk Assessment Work Plan and Methodology

September 2003

Figure 4.2:

Exposure Units with PACs

File: W:\Projects\Fy2003\eco\eco.apr

May 30, 2003

CERCLA Administrative Record Document, SW-A-004835

U S DEPARTEMENT OF ENERGY
ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE

GOLDEN, COLORADO

32

Assessment of Functional Areas

The EUs are representative of expected activity areas for the WRW or WRV receptors The areas of the EUs vary from 398 to 1,069 acres, as shown in Table 4 3 Time-weighted activity areas for refuge personnel calculated from survey data collected for the Rocky Mountain Arsenal (RMA) are in the same size range, according to Table 4 4 The areas were calculated using the estimated time spent in each area size class, using the following formula

$$\textit{Time-Weighted Area} = \sum_{i=1 \text{ to } 3} (t_i/t_t * A_i) \qquad \text{(Equation 4-1)}$$

where

t_i = the time spent in the ith area size class by all workers

t_t = the total time spent in all area size classes by all workers

A_i = the ith area (midpoint or maximum of size range)

Table 4.3 RFETS EU Areas

EU	Area (acres)
Industrial Area	428
Woman Drainage	977
South Buffer Zone Area	1,069
Wind Blown Area	720
Upper Walnut Drainage	403
Lower Walnut Drainage	398
No Name Gulch Drainage	425
Inter-Drainage	591
Rock Creek Drainage	765
West Area	471

Table 4.4 Time-Weighted Average Activity Areas for WRWs*

Receptor	Parameter	Small Area (0-10 acres)	Medium Area (10-500 acres)	Large Area (500-6000 acres)
	Midpoint size of area (acres)	5	255	3,250
	Max size of area (acres)	10	500	6,000
All workers	Midpoint time-weighted area (acres)	2	126	332
	Midpoint EU size (time-weighted) (acres)	**460**		
	Max time-weighted area (acres)	4	248	613
	Max EU size (time-weighted) (acres)	**865**		
Workers spending at least 50 percent of time outdoors	Midpoint time-weighted area (acres)	1 9	132	319
	Midpoint EU size (time-weighted) (acres)	**453**		
	Max time-weighted area (acres)	3 8	260	589
	Max EU size (time-weighted) (acres)	**852**		
Workers spending at least 30 percent of time outdoors and on Site 100 percent of time	Midpoint time-weighted area (acres)	2	133	425
	Midpoint EU size (time-weighted) (acres)	**560**		
	Max time-weighted area (acres)	3	261	784
	Max EU size (time-weighted) (acres)	**1,048**		
All workers spending at least 30 percent of time outdoors	Midpoint time-weighted area (acres)	1 8	132	421
	Midpoint EU size (time-weighted) (acres)	**555**		
	Max time-weighted area (acres)	3 5	260	777
	Max EU size (time-weighted) (acres)	**1,040**		

* Calculated from original survey data from Table B 2-14 (RMA IEA/RC Appendix B, 8/93) (reported times at middle and higher activities, outdoors) and from Table B 2att2-1,2,3,4,5,& 6 (RMA IEA/RC Appendix B, 2/15/94) (reported times doing specific tasks) Survey was performed by Shell for the Army's Baseline Risk Assessment for the RMA WRWs from Malheur, OR (M), Minnesota Valley, MN (MV), and Crab Orchard, IL (CO) were included in the survey Carl Spreng and Diane Niedzwiecki of CDPHE then exercised professional judgment to decide land area for each task

The EUs are also indicative of different functional areas Activities performed in the drainages will vary from those performed in the upland areas due to variation in topography, vegetation, and habitat The combination of the assessment of risks in the EUs and AOCs, which represent areas of intensive activity, will result in a complete assessment of the potential range in risks from residual contamination at the Site

Compliance with RFCA/CERCLA Requirements

Under CERCLA, it must be shown that risks for expected land uses at the Site fall within the acceptable range of 1×10^{-6} to 1×10^{-4} cancer risks and below an HI of 1 for noncarcinogenic effects The assessments for the EUs will present a comprehensive evaluation of long-term risks to the designated receptors across the Site The coupling of these results with assessments of the targeted AOCs will provide estimates of residual risks from the Site following accelerated actions

34

4.2.3 EUs for the WRW

As discussed above, EUs for the WRW, shown on Figure 4 1, incorporate information on contaminant releases and watershed and drainage features, and are based on anticipated activity patterns These EUs form the basis for the assessment of risks to the anticipated major receptor in the CRA, recognize distinct areas of contamination, and support land use planning The EU assessment will be augmented with the AOC analysis and assessments Together, they will provide a complete assessment of risks to the WRW

The assessments for the EUs represent the risks a worker will encounter in discharging his or her duties across the Site The nature of the work involves movement over the entire Site Therefore, relatively small EUs do not represent true estimates of long-term risks to the worker However, due to the nature of the distribution of residual contamination across the Site, some areas represent a greater risk to the worker The combination of the EU assessments with the AOC assessments addresses this concern The EU assessments will provide a realistic evaluation of long-term risks at the Site, while the AOC assessments will provide risk information on a localized basis

The risk assessment flow for each WRW EU is given below

1 The areas of the EUs are set forth in this Methodology

2 All surface soil, sediment, and subsurface soil sampling locations to a depth of 8 feet will be assessed at each EU for the WRW scenario

3 A DQA will be performed on the samples in each EU to ensure that the data within each are of sufficient quantity and quality to perform a risk assessment

4 The COC selection process will be applied to surface soil, sediments, and subsurface soil to a depth of 8 feet

5 Data from the COC selection process will be used to determine AOCs to be assessed (Section 4 2 5)

6 Data will be aggregated by EU and risks will be characterized

4.2.4 EUs for the WRV

The refuge visitor is envisioned as participating in a variety of activities at the wildlife refuge The visitor may or may not be under the guidance and oversight of a WRW Therefore, the same EUs will be applied to assess risks to the WRV as for the WRW Due to the less intensive usage of the Site by the visitor, an assessment by AOC will not be performed

The risk assessment flow for each WRV EU is given below

1 The EUs are set forth in this Methodology

2 All surface soil and sediment sampling locations in each EU will be assessed for the WRV scenario

3 Surface soil and sediments will be combined for the COC selection process

35

4 A DQA will be performed on the samples in each EU to ensure that the data within each are of sufficient quantity and quality to perform a risk assessment.

5 Data will be aggregated by EU and risks will be characterized

4.2.5 Defining and Assessing AOCs

This section outlines how the AOCs to be used for the CRA will be developed for the onsite WRW The AOCs to be used in the CRA differ in the way they are defined and in their purpose from those used in the accelerated action process In the accelerated action process as presented in the Industrial Area Sampling and Analysis Plan (IASAP) (DOE 2001), an AOC is defined as an area in which concentrations of organics are above detection limits or concentrations of inorganics are above background concentrations plus two standard deviations The constituents with concentrations above detection limits or background levels are then compared to the ALs presented in Attachment 5 of RFCA (DOE et al 1996 [as modified]) The purpose is to identify areas for accelerated actions

The AOCs for risk assessment are defined in a slightly different manner, using risk-based concentrations of PCOCs In the CRA, an AOC is defined as an area with concentrations of one or more constituents above a PRG, as presented in Appendix N of Appendix 3 of RFCA (DOE et al 1996 [as modified]) or above a screening-level PRG (Appendix A of this document) The method is described in detail below The purpose of AOCs for the CRA is to identify areas of the Site that may pose greater health risks to anticipated receptors

AOCs for the WRW

The onsite WRW exposure scenario will be assessed across all areas at RFETS on an AOC basis The AOC for the WRW will be smaller than the EUs because a WRW may be exposed across a smaller area Therefore, COC concentrations will be averaged over a smaller area for this exposure scenario. The extent of an AOC for the WRW will be less than the EU and will be determined by the results of the PRG screen described in Section 4 4

The CRA DQA and exposure assessment provide the information for deriving the AOCs The DQA determines whether the data are of sufficient quantity and quality for use in the risk assessment The PRG screen in the exposure assessment removes all contaminants from consideration that have such a low risk that they can be dropped from the risk assessment

The areal extent of the AOC for the WRW will be defined using the following steps

1 All surface soil/sediment and subsurface soil sampling locations at RFETS will be compared with the onsite WRW PRGs for a risk = 1 x 10^{-6} and a hazard quotient (HQ) = 0 1 It is possible that surface and subsurface AOCs will not occur in the same locations

2 The AOC will be defined as the area surrounding the location(s) with concentrations above the WRW PRGs where organics are present above the detection limits and metals/radionuclides are present above background levels for each COC

3 The remaining steps of the COC selection process will then be applied to the AOC If COCs exist, a risk assessment will be performed

4 A DQA will be performed on the samples in each AOC to ensure that the data within each are of sufficient quantity and quality to perform a risk assessment

5. Human health risks will be developed for all COCs within each AOC

4.3 Data Aggregation for Risk Assessment

Analytical results from sampling and contaminant concentrations estimated from transport modeling that meet the DQO and DQA requirements will be used to estimate human health and ecological risks on an EU/AOC basis (Section 4 2) The types of data aggregation to be performed for the HHRA are outlined in Table 4 5 Data for surface soil, subsurface soil, and sediments will be aggregated on an EU and AOC basis to estimate exposure concentrations and intakes to perform the CRA

Table 4.5 Data Aggregation for the CRA

Exposure Scenario	Media	EU	Area of Concern
WRW	Surface Soil and Sediment	Yes	Yes
	Subsurface Soil	Yes	Yes
WRV	Surface Soil and Sediment	Yes	No
	Subsurface Soil	No	No

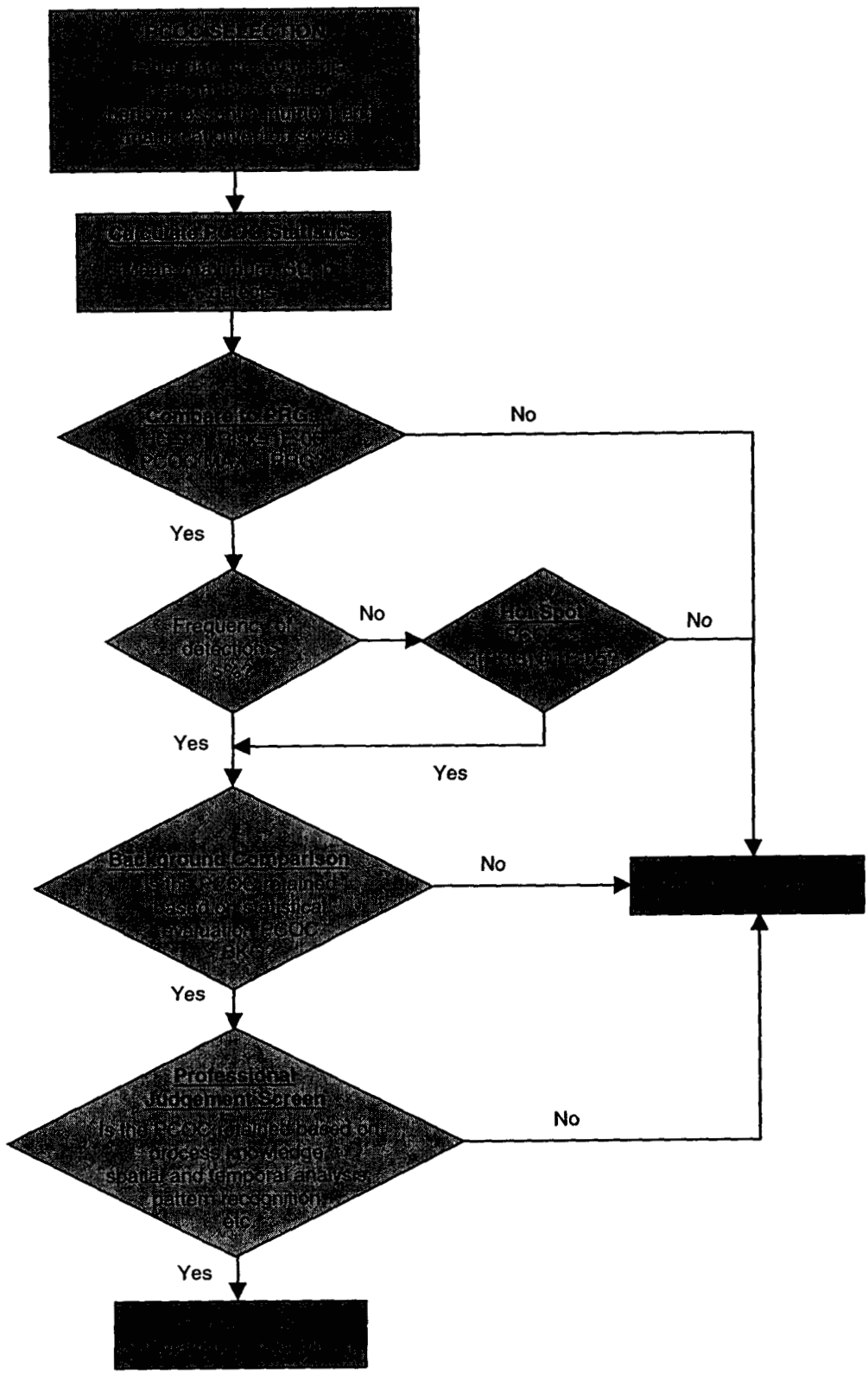
4.4 COC Identification and Selection

COCs will be selected for each media and identified on an EU and AOC basis COCs will be determined for each individual EU and AOC because historical use of chemicals varied across the Site The COC lists will be developed using the WRW PRGs or screening-level PRGs The WRW PRGs are documented in Appendix N of Appendix 3 of RFCA (DOE et al 1996 [as modified]) Screening-level PRGs have been developed specifically for the CRA for WRW exposure to subsurface soil, inhalation of volatiles in indoor air, and ingestion of surface water These risk-based values will only be used for the CRA and will not be placed in RFCA The screening-level PRGs are documented in Appendix A The WRW COCs will also be used for the WRV scenario

4.4.1 Selection of EU and AOC COCs

The selection of EU and AOC COCs will follow the process outlined on Figure 4 4 The process will be repeated for each EU and AOC Environmental media that will be included in the COC selection process are surface soil, sediment, and subsurface soil

Figure 4.4 EU/AOC COC Selection Process



Best Available Copy

4.4.2 DQA

Data will be extracted and the DQA will be conducted to assess the quality of reported data as described in Section 3 1 5 Outliers will also be assessed using standard statistical testing and eliminated, if appropriate

4.4.3 Data Aggregation

The data that pass the DQA process will be aggregated by area (i e , EU and AOC)), media (e g , surface soil), and analyte prior to initiation of the COC screening process A value of one-half the reported value will be used for all U-qualified (nondetect) inorganic and organic data (EPA 1989) This does not apply to radionuclides, for which reported values will be used in all cases A summary presentation of the data will include

- Chemical name,
- Chemical Abstract Service (CAS) number,
- Chemical-specific, contract-required quantitation limit (CRQL),
- Reported detection limit,
- Number of samples;
- Frequency of detection,
- Minimum detected concentration, maximum detected concentration,
- Arithmetic mean concentration, and
- Standard deviation

4.4.4 Elimination of Essential Nutrients/Major Cations and Anions

Intakes calculated based on maximum concentrations of essential nutrients in soil and sediment samples that have no toxicity values will be compared to daily reference intakes (DRIs) and upper limit daily nutrient intakes (ULs) in accordance with EPA guidance (1989) All essential nutrients that fall within the range of recommended or maximum daily intakes (NAS 2000, 2002) will be eliminated from further consideration in the CRA

Nitrate, nitrite, ammonium, and fluoride have oral toxicological factors and will be assessed in the surface water screen Nitrate will also be assessed in soil, due to its presence in groundwater Sulfide, bicarbonate, bromide, carbonate, chloride, orthophosphate, and sulfate have no toxicological factors and will be eliminated from assessments in soil and sediments

4.4.5 PRG Screen

All remaining PCOCs will be screened against the WRW PRGs presented in Appendix 3, Implementation Guidance Document, Appendix N, Preliminary Remediation Goals (DOE et al 1996 [as modified]) and the screening-level PRGs presented in Appendix A for the appropriate media using an HQ of 0 1 or risk of 1 x 10^{-6} All PCOCs below the WRW PRGs will be eliminated for an EU and any AOC within the EU The PRG ratios for each PCOC will be presented in tables

4.4.6 Detection Frequency Filter

Compounds detected at a frequency of 5 percent or greater will be carried through the COC selection process Compounds detected at less than 5 percent frequency are not considered characteristic of Site contamination and the potential for exposure is low

All analytes with less than 5 percent detection frequency will be compared to Site PRGs set to an HQ of 3 0 or risk of 3 x 10^{-5} as a health-protective precaution as agreed upon and documented in the IASAP (DOE 2001) If the maximum detected value of an infrequently detected contaminant (less than 5 percent) exceeds the screening value, it will be carried on in through COC screening process

4.4.7 Data Distribution Testing

Data distribution testing will be performed for all PCOCs retained following the PRG and frequency screens to aid in deciding the statistical test to use for comparison to background Testing will be conducted following EPA guidance (EPA 2002b) and EPA QA/G-9 methods (EPA 2000b) The statistical tests to be used for determining data distributions are

- Shapiro-Wilk Test (S-W) (test limited to n > or = 30 and < or = 50), and
- D'Agostino's Test (D'Agostino) (n > 50)

The test will be chosen based on sample size as recommended by EPA (2002b) Data sets with less than 30 samples will be considered lognormally distributed If the chosen test identifies the distribution as normal, testing will stop and the data will be considered normally distributed If not, the data will be log-transformed and tested again The data will then be assigned a lognormal or nonparametric distribution, depending on the results The assigned distribution will then be used to determine the appropriate test for the background comparison and estimate an appropriate upper 95UCL concentration

4.4.8 Background Analysis

Following the determination of data distributions, inorganic and radionuclide PCOCs will be compared statistically to background data sets to determine whether the PCOCs are present at concentrations above background

The background comparison is used to distinguish between contamination associated with Site activities and nonanthropogenic (naturally occurring) background conditions The Geochemical Characterization of Background Surface Soils Background Soils Characterization Program, Final Report (DOE 1995a) will be used for the surface soil background data The Background Geochemical Characterization Report (DOE 1993a) will be used for the remaining media types Background comparisons will be performed in accordance with current EPA guidance (2002b)

The statistical test chosen for a particular PCOC depends on the distributions of the PCOC and background data Either parametric or nonparametric tests can be used, although neither work well with small data sets of less than 25 samples (EPA 2002b) Therefore, it is important that a combination of statistical testing and other comparison methods, including graphical, 95UCLs, outlier testing, and comparison of maximum values, be used to compare the populations The Wilcoxon (aka Mann-Whitney) Rank Sum Test is useful when Site and background data have different assigned distributions or are both nonparametric (i e , not

normally or lognormally distributed) If Site and background data have the same normal or lognormal distributions, a Student's t-test can be used to compare PCOCs to background. Lognormal data are log-transformed prior to conducting a standard t-test Evaluation of 95 percent confidence intervals for Site and background data can also be useful Overlap of 95 percent confidence intervals indicates the Site data are within the range of natural background

If the concentrations for a particular PCOC are found to be significantly greater than background levels, the PCOC will be retained for further consideration Following the background comparison, professional judgment will be applied and the final list of COCs will be determined

4.4.9 Professional Judgment

Professional judgment is also used to include or exclude a PCOC from the final COC list A PCOC that has been previously eliminated may be included because of a preponderance of historical data suggesting the chemical may have been released in significant quantities to the environment Professional judgment can also be applied to develop a weight of evidence argument to exclude a PCOC based on data assessment, or spatial, temporal, or pattern-recognition concepts

Data assessment includes an evaluation of laboratory and validation qualifiers Spatial analysis requires that concentrations of each PCOC be plotted on a map, assessment of the plotted data should indicate their presence (or absence) or any trends in concentration, and assist in delimiting hot spots

Temporal analysis is particularly relevant for groundwater data, where repeated sampling at a well offers the opportunity to evaluate changes in analyte concentrations over time Time-series plots are used for this evaluation Temporal analysis of data for sediments or other geologic materials is less useful and may not even be applicable

Pattern recognition includes

- Interelement correlations,
- Similarities in geochemical behavior,
- Correlations between elemental concentrations and certain parameters (total suspended solids [TSS], the negative logarithm of the hydrogen ion activity [pH], reduction-oxidation potential [Eh or pe, where Eh=0 059*pe], clay content, organic content, cation-exchange capacity, and so forth), and
- Other recognizable patterns in elemental behavior

Professional judgment will be applied on a case-by-case basis All such judgment will be supported by a thorough analysis of the available evidence Maps, figures, and references supporting the professional judgment will be presented

4.4.10 Presentation of COCs

The COC selection process will be documented in tables, such as Table 4 6, that will summarize the data for each analyte chosen as a COC in each medium

41

Table 4.6 Rationale for Selecting COCs

Analyte	PRG Ratio	Detection Frequency (%)	Hot Spot Ratio	Background Comparison	Professional Judgment	COC

4.5 Pathway Significance Evaluations

Two pathways for the WRW are currently considered to have insignificant contributions to risk

- Ingestion of contaminants transported from groundwater to surface water
- Inhalation of contaminants volatilizing from groundwater and soil

Evaluations will be completed to ensure that the designation as insignificant is appropriate The evaluations are described below

4.5.1 Groundwater-to-Surface Water Pathway

In the WRW scenario, the worker is potentially exposed to contaminants in surface water by ingestion while working This pathway is currently considered insignificant If contaminants known to be present in groundwater are transported to surface water in sufficient concentrations, this pathway could become a significant contributor to risk The results of groundwater transport modeling can resolve this issue Groundwater modeling for the Site is being done for a variety of purposes, one of which is to support the CRA The objective of the transport modeling in support of the CRA is to simulate transport of contaminants from groundwater to surface water, and estimate future exposure concentrations in surface water for potential onsite receptors A subsurface water transport model is under development to estimate surface water concentrations for the analytes selected by a screening procedure, using surface water PRGs developed for WRW (Appendix A) and ecological receptor (DOE et al 1996 [as modified]) exposures to surface water

The estimated concentrations after 30 years at select surface water locations will be subjected to the COC selection process in the CRA Results will be used to estimate potential human health or ecological effects from surface water concentrations resulting from the transport of contaminants currently in groundwater The transport model will be calibrated using available information on contaminant sources, current contaminant distributions, and

42

historical concentrations over time DQOs for the modeling effort will accompany its documentation

4.5.2 Groundwater/Subsurface Soil-to-Air Pathway

In the WRW scenario, the worker is potentially exposed to contaminants in groundwater that volatilize and are transported through the soil and released to the atmosphere, where they can be inhaled by the worker Exposure to volatilized contaminants can occur indoors or outdoors These pathways are both currently considered insignificant The indoor route is considered a greater contributor to risk due to inhibited air exchange. If contaminants known to be present in groundwater are transported to the soil surface and then to the atmosphere in sufficient concentrations, the indoor pathway could become a significant contributor to risk The WRW scenario currently includes an indoor component An evaluation will be performed using the PRGs presented in Appendix A to determine whether indoor inhalation of volatilized subsurface contamination is a significant source of risk

4.6 EPCs

The EPC of a COC in a sampled medium is quantified using the 95UCL on the arithmetic mean (EPA 1989) The arithmetic mean is a statistically robust estimator, even when normality assumptions are not met (Gilbert 1987) The 95UCL on the mean is a conservative estimate of the average concentration to which receptors would be exposed over time in an exposure area If the maximum detected COC value is below the 95UCL, the maximum concentration is used as the EPC When data distributions are demonstrated to be lognormal, an arithmetic mean and 95UCL will be calculated using log-transformed data When distributions are found to be neither normal nor lognormal, a nonparametric 95UCL will be calculated (EPA 2002a)

The one-sided confidence limit calculated using the Student's t-statistic will be used for normally distributed data with 30 or more samples (Gilbert 1987) EPA guidance (2002a) contains recommendations for several calculation methods for lognormally distributed data Rather than use a battery of tests, the Chebychev inequality for calculation of the 95UCL has been chosen due to its versatility The Chebychev method will be used for all lognormally distributed data and for data sets with less than 30 samples

A Bootstrap nonparametric, probabilistic resampling methodology will be used to determine the 95UCL when observed data are not normally or lognormally distributed and have 30 or more samples Bootstrap calculations of the 95UCL avoid difficulties associated with empirically determining the shape of the observed distribution because it has no distributional assumptions This resampling technique provides estimates of the mean and variance for any distribution regardless of the specific shape and "performs substantially better, sometimes orders of magnitude better, in estimating the 95UCL of the mean from positively skewed data sets " than other methods (EPA 1997) A normal Bootstrap program will be used to derive all mean and variance estimates The Bootstrap method will be used to calculate EPC terms for estimating risk, as presented in EPA guidance (2002a) Estimates derived for the CRA will be developed using 2,000 or more resampling events Use of 1,000 iterations has been demonstrated to be sufficient for estimating the mean and associated variance (DOE 2003)

EPCs will be estimated at human receptor locations for all pertinent environmental media, including surface and subsurface soil and sediment The physical, chemical, and hydrogeologic characteristics of the Site must therefore be adequately studied and understood Steady-state conditions will be assumed for EPCs based on direct environmental monitoring data Effects of dilution, dispersion, source-term depletion, erosion, biodegradation, and sorption on quantification of the EPCs will be addressed in the uncertainty section of the CRA EPCs will be estimated to realistically predict long-term averages and impacts to receptors

EPCs for human receptors will be determined using measured environmental monitoring data Subsurface soil concentrations will be used to estimate source terms for the possible transport of contaminants to groundwater and surface water locations and subsequent direct ingestion by human receptors

4.6.1 Intake Calculations

Intake to receptors will be quantified for each selected COC, exposure pathway, and exposure scenario Exposure factors reported in Section 4 1 will be used in the CRA Intake in units of mg/kg per day will be calculated for all receptors exposed to ingestion, dermal, and inhalation pathways using the general formulas below Radiological intake in units of picocuries (pCi) will be assessed using the standard EPA formulas External radionuclide exposure is calculated in units of years per picocurie per gram (yr/pCi/g)

The equations for calculating intakes for the WRW and WRV are provided in Tables 4 7 and 4 8 The abbreviations and specific values used for the exposure factors are defined in Tables 4 1 and 4 2

Intakes are averaged over different time periods for carcinogenic and noncarcinogenic chemicals For carcinogens, intakes are calculated by averaging the total cumulative dose during the exposure period over a lifetime, yielding a "lifetime average daily intake" (EPA 1989) For noncarcinogenic chemicals, intakes are calculated by averaging over the period of exposure to yield an average daily intake Different averaging times are used for carcinogens and noncarcinogens because their effects occur by different mechanisms The approach for carcinogens is based on the hypothesis that a high dose received over a short period of time is equivalent to a corresponding low dose spread over a lifetime The intake of a carcinogen is averaged over a 70-year lifetime regardless of exposure duration

For calculation of radionuclide intakes, the exposure concentration is expressed in picocuries per liter (pCi/L), and the expression is not divided by body weight or averaging time The resulting intake for radionuclides is expressed in pCi

Table 4.7 Intake Equations for the WRW

Wildlife Range Worker
Surface Soil and Sediment Intake Equations
Intake Equation for WRW Ingestion
Nonradionuclide Intake (mg/kg-day) = $\frac{(Cs \times IRwss \times EFwss \times EDw \times CF1)}{(BWa \times [ATc \text{ or } ATnc]^2)}$
Radionuclide Intake (pCi) = Cs x IRwss x EFwss x EDw x CF3
Intake Equation for WRW Dermal Contact
Nonradionuclide Intake (mg/kg-day) = $\frac{(Cs \times EFwss \times EDw \times EVw \times SAw \times AFw \times ABS \times CF1)}{(BWa \times [ATc \text{ or } ATnc]^*))}$
Intake Equation for WRW Outdoor Inhalation of Suspended Particulates
Nonradionuclide Intake (mg/kg-day) = $\frac{(Cs \times IRaw \times EFwss \times EDw \times ETw \times ETo\_w \times MLF)}{(BWa \times [ATc \text{ or } ATnc]^2)}$
Radionuclide Intake (pCi) = Cs x IRaw x EFwss x EDw x ETw x ETo_w x MLF x CF2
Intake Equation for WRW Indoor Inhalation of Suspended Particulates
Nonradionuclide Intake (mg/kg-day) = $\frac{(Cs \times IRaw \times EFwss \times EDw \times ETw \times ETi\_w \times DFi \times MLF)}{(BWa \times [ATc \text{ or } ATnc]^2)}$
Radionuclide Intake (pCi) = Cs x IRaw x EFwss x EDw x ETw x ETi_w x DFi x MLF x CF2
Exposure Equation for WRW Outdoor External Radiation
Radionuclide Exposure (yr*pCi/g) = Cs x Te_A x Te_Do x EDw x ACF x GSFo
Exposure Equation for WRW Indoor External Radiation
Radionuclide Exposure (yr*pCi/g) = Cs x Te_A x Te_Di x EDw x ACF x GSFi
Subsurface Soil Intake Equations
Intake Equation for WRW Ingestion
Nonradionuclide Intake (mg/kg-day) = $\frac{(Cs \times IRwss \times EFwsub \times EDw \times CF1)}{(BWa \times [ATc \text{ or } ATnc]^2)}$
Radionuclide Intake (pCi) = Cs x IRwss x EFwsub x EDw x CF3
Intake Equation for WRW Dermal Contact
Nonradionuclide Intake (mg/kg-day) = $\frac{(Cs \times EFwsub \times EDw \times EVw \times SAw \times AFw \times ABS \times CF1)}{(BWa \times [ATc \text{ or } ATnc]^2)}$
Intake Equation for WRW Outdoor Inhalation of Suspended Particulates
Nonradionuclide Intake (mg/kg-day) = $\frac{(Cs \times IRaw \times EFwsub \times EDw \times ETw \times ETo\_w \times MLF)}{(BWa \times [ATc \text{ or } ATnc]^2)}$
Radionuclide Intake (pCi) = Cs x IRaw x EFwsub x EDw x ETw x ETo_w x MLF x CF2
Exposure Equation for WRW Outdoor External Radiation
Radionuclide Exposure (yr*pCi/g) = Cs x Te_As x Te_Do x EDw x ACF x GSFo

1 Definitions of abbreviations can be found in Table 4 1

2 Carcinogenic (ATc) or noncarcinogenic (ATnc) averaging times are used in equations, depending on whether carcinogenic or noncarcinogenic intakes are being calculated

Table 4.8 Intake Equations for the WRV

Wildlife Receptor
Intake Equations for WRV Ingestion of Soil
Nonradionuclide Intake (mg/kg-day) = $\frac{(Cs \times SIRageav \times EFv \times CF1)}{[ATc \text{ or } ATnc]^2}$
Radionuclide Intake (pCi) = Cs x SIRagav_r x EFv x EDt x CF3 units
Intake Equation for WRV Dermal Contact with Soil
Nonradionuclide Intake (mg/kg-day) = $\frac{(Cs \times EFv \times EVv \times SFSagav \times ABS \times CF1)}{[ATc \text{ or } ATnc]^2}$
Intake Equations for WRV Inhalation of Surface Soil
Nonradionuclide Intake (mg/kg-day) = $\frac{(Cs \times IRagav \times EFv \times MLF)}{[ATc \text{ or } ATnc]^2}$
Radionuclide Intake (pCi) = Cs x Iragav_r x EFv x (EDav + EDcv) x ETv x MLF x CF2
Exposure Equation for WRV External Radiation from Surface Soil
Radionuclide Intake (yr*pCi/g) = Cs x Te_Av x Te_Dv x ACF x GSFo

1 Definitions of abbreviations can be found in Table 4 2

2 Carcinogenic (ATc) or noncarcinogenic (ATnc) averaging times are used in equations, depending on whether carcinogenic or noncarcinogenic intakes are being calculated

5.0 HUMAN HEALTH TOXICITY ASSESSMENT

Toxicity values are used to characterize risk, while toxicity profiles summarize toxicological information for radioactive and nonradioactive COCs Toxicity information is summarized for two categories of potential effects noncarcinogenic and carcinogenic These two categories have slightly differing methodologies for estimating potential health risks associated with exposures to carcinogens and noncarcinogens

In general, toxicity profiles are obtained from EPA's Integrated Risk Information System (IRIS) IRIS contains only those toxicity values that have been verified and undergone extensive peer review by EPA's Reference Dose or Carcinogenic Risk Assessment Verification Endeavor (CRAVE) Work Groups The IRIS database is updated monthly and supercedes all other sources of toxicity information

If the necessary data are not available in IRIS, EPA's most recent issue of Health Effects Assessment Summary Tables (HEAST) will be used It contains a comprehensive listing of provisional risk assessment information that has undergone review and has the concurrence of individual EPA Program Offices, but has not had the extensive review to be recognized agency-wide as consensus information Values that have been withdrawn will not be used quantitatively unless the regulatory agency toxicologists (CDPHE and EPA) concur with their use for the CRA Provisional values for toxicity factors are often available from EPA's National Center for Environmental Assessment These will be used with the concurrence of EPA and CDPHE toxicologists EPA's HEAST for Radionuclides will be used as guidance for calculating radionuclide-specific cancer risk (EPA 2001a) Route-to-route extrapolation of toxicity values will not be performed at RFETS except where oral criteria are used for dermal exposures Consensus will be sought on all toxicity values used in the CRA

Secondary sources of information will be used qualitatively in the HHRA EPA toxicologists, both regional and national, may also serve as information sources All information sources

46

will be documented in the toxicity assessment In general, the toxicity factors used for the Site PRGs will be used in the CRA, unless updates become available

5.1 Identification of Toxicity Values for Carcinogenic Effects

Potential carcinogenic risks will be expressed as an estimated probability that an individual might develop cancer from lifetime exposure This probability is based on projected intakes and chemical-specific dose-response data called "cancer slope factors (CSFs) " CSFs and the estimated daily intake of a compound, averaged over a lifetime, are used to estimate the incremental risk that an individual exposed to that compound may develop cancer There are two classes of potential carcinogens chemical carcinogens and radionuclides

5.1.1 Chemical Carcinogens

Evidence of chemical carcinogenicity originates primarily from two sources lifetime studies with laboratory animals and human (epidemiological) studies Animal data from laboratory experiments represent the primary basis for the extrapolation for most chemical carcinogens Experimental results are extrapolated across species (i e , from laboratory animals to humans), from high-doses regions (i e , levels to which laboratory animals are exposed) to low-doses regions (i e , levels to which humans are likely to be exposed in the environment), and across routes of administration (e g , inhalation versus ingestion)

EPA estimates human cancer risks associated with exposure to chemical carcinogens on an administered-dose basis It is assumed a small number of molecular events can evoke changes in a single cell that can lead to uncontrolled cellular proliferation and tumor induction This mechanism for carcinogenesis means there is theoretically no level of exposure to a given chemical carcinogen that does not pose a small, but finite, probability of generating a carcinogenic response

The CSFs are estimated using the linearized multistage model The basis of this model is that multiple events may be needed to yield tumor induction (Crump et al 1977) reflecting the biological variability in tumor frequencies observed in animal and human studies The dose-response relationship predicted by this model at low doses is essentially linear The CSFs calculated for nonradiological carcinogens using the multistage model represent the 95UCL of the probability of a carcinogenic response Consequently, risk estimates based on these CSFs are conservative estimates representing upper-bound estimates of risk

Uncertainties in the toxicity assessment for chemical carcinogens are dealt with by classifying each chemical into one of several groups, according to the EPA-defined, weight-of-evidence from epidemiological studies and animal studies These groups are listed in Table 5 1

Table 5.1 Carcinogen Groups

Weight-of-Evidence	Description
A	Human carcinogen (sufficient evidence of carcinogenicity in humans)
B	Probable human carcinogen (B1 - limited evidence of carcinogenicity in humans, B2 - sufficient evidence of carcinogenicity in animals with inadequate or lack of evidence in humans)
C	Possible human carcinogen (limited evidence of carcinogenicity in animals and inadequate or lack of human data)
D	Not classifiable as to human carcinogenicity (inadequate or no evidence)
E	Evidence of noncarcinogenicity for humans (no evidence of carcinogenicity in adequate studies)

The oral and inhalation CSFs for the COCs will be compiled in a table Table 5 2 presents the current CSFs used for calculation of the PRGs These values will be updated as part of the RFCA annual review and incorporated into the CRA A similar table of values will be included in the CRA

5.1.2 Radionuclides

A series of federal guidance documents have been issued by EPA for the purpose of providing federal and state agencies with technical information to assist their implementation of radiation protection programs The HEAST for Radionuclides (EPA 2001a) provides numerical factors, called "risk coefficients," for estimating risks to health from exposure to radionuclides This federal guidance will be used to calculate risk from radionuclides It applies state-of-the-art methods and models that take into account age and gender dependence on intake, metabolism, dosimetry, radiogenic risk, and competing causes of death in estimating the risks to health from internal or external exposure to radionuclides

A "morbidity risk coefficient" is provided for a given radionuclide and exposure mode This coefficient is an estimate of the average total risk of experiencing a radiogenic cancer, regardless of whether the cancer is fatal The risk coefficient associated with morbidity will be used to characterize human health risks Current values used are shown in Table 5 3

5.2 Identification of Toxicity Values for Noncarcinogenic Effects

Potential noncarcinogenic effects will be evaluated in the risk characterization by comparing daily intakes (calculated in the exposure assessment) with chronic reference doses (RfDs) developed by EPA A chronic RfD is an estimate (with uncertainty spanning perhaps an order of magnitude) of the daily exposure that can be incurred during a lifetime, without an appreciable risk of a noncancer effect being incurred in human populations, including sensitive subgroups (EPA 1989) The RfD is based on the assumption that thresholds exist for noncarcinogenic toxic effects (e g , liver or kidney damage) Adverse effects are not expected to occur with chronic daily intakes below the RfD value

48

Table 5.2 Nonradiological Toxicity Constants

Target Analyte List Chemical[1]		CAS Number	Oral RfD (mg/kg-day)		Oral/Ingestion Slope Factor (mg/kg-day)$^{-1}$		Inhalation RfD[2] (mg/kg-day)		Inhalation Slope Factor[2] (mg/kg-day)$^{-1}$		Dermal ABS[3] Fraction Absorbed
Acenaphthene	(V)	83-32-9	0 06	I							0 13
Acetone	(V)	67-64-1	0 1	I							
Aldrin		309-00-2	0 00003	I	17	I			17	I	0 1
Aluminum		7429-90-5	1	E			0 001	E			
Anthracene	(V)	120-12-7	0 3	I							0 13
Antimony		7440-36-0	0 0004	I							
Aroclor-1016		12674-11-2	0 00007	I	0 07	I			0 07	Ia	0 14
Aroclor-1221		11104-28-2			2	Ia			0 4	Ia	0 14
Aroclor-1232		11141-16-5			2	Ia			0 4	Ia	0 14
Aroclor-1242		53469-21-9			2	Ia			0 4	Ia	0 14
Aroclor-1248		12672-29-6			2	Ia			0 4	Ia	0 14
Aroclor-1254		11097-69-1	0 00002	I	2	Ia			0 4	Ia	0 14
Aroclor-1260		11096-82-5			2	Ia			0 4	Ia	0 14
Arsenic		7440-38-2	0 0003	I	1 5	I			15 05	I	0 03
Barium		7440-39-3	0 07	I			0 0001429	A			
Benzene	(V)	71-43-2	0 003	E	0 055	I	0 0017	E	0 029	I	
alpha-BHC		319-84-6			6 3	I			6 3	I	0 04
beta-BHC		319-85-7			1 8	I			1 8	I	0 04
delta-BHC		319-86-8									0 04
gamma-BHC (Lindane)		58-89-9	0 0003	I	1 3	H					0 04
Benzo(a)anthracene		56-55-3			0 73	E					0 13
Benzo(a)pyrene		50-32-8			7 3	I			0 31	E	0 13
Benzo(b)fluoranthene		205-99-2			0 73	E					0 13
Benzo(k)fluoranthene		207-08-9			0 073	E					0 13
Benzoic Acid (at pH 7)		65-85-0	4	I							
Benzyl Alcohol		100-51-6	0 3	H							
Beryllium		7440-41-7	0 002	I			5 71E-06	I	8 4	I	
bis(2-chloroethyl)ether	(V)	111-44-4			1 1	I			1 1	I	
bis(2-chloroisopropyl)ether	(V)	39638-32-9	0 04	I	0 07	H			0 035	H	

Table 5.2 Nonradiological Toxicity Constants

Target Analyte List Chemical[1]		CAS Number	Oral RfD (mg/kg-day)		Oral/Ingestion Slope Factor (mg/kg-day)$^{-1}$		Inhalation RfD[2] (mg/kg-day)		Inhalation Slope Factor[3] (mg/kg-day)$^{-1}$		Dermal ABS[4] Fraction Absorbed
bis(2-ethylhexyl)phthalate		117-81-7	0 02	I	0 014	I			0 014	E	0 1
Bromodichloromethane	(V)	75-27-4	0 02	I	0 062	I					
Bromoform	(V)	75-25-2	0 02	I	0 0079	I			0 0039	I	
Bromomethane (methyl bromide)	(V)	74-83-9	0 0014	I			0 0014286	I			
2-Butanone (methyl ethyl ketone)	(V)	78-93-3	0 6	I			0 2857143	I			
Butylbenzylphthalate		85-68-7	0 2	I							0 1
Cadmium (water)		7440-43-9	0 0005	I					6 3	I	
Cadmium (food)		7440-43-9	0 001	I			0 000057	E	6 3	I	0 001
Carbon disulfide	(V)	75-15-0	0 1	I			0 2				
Carbon tetrachloride	(V)	56-23-5	0 0007	I	0 13	I	0 000571	E	0 053	I	
alpha-Chlordane		5103-71-9	0 0005	I	0 35	I	0 0002	b	0 35	b	0 04
beta-Chlordane		5103-74-2	0 0005	I	0 35	I	0 0002	b	0 35	b	0 04
gamma-Chlordane		12789-03-6	0 0005	I	0 35	I	0 0002	b	0 35	b	0 04
4-Chloroaniline		106-47-8	0 004	I							0 1
Chlorobenzene	(V)	108-90-7	0 02	I			0 017	E			
Chloroethane (ethyl chloride)	(V)	75-00-3	0 4	E	0 0029	E	2 8571429	I			
Chloroform	(V)	67-66-3	0 01	I			0 000086	E	0 0805	I	
Chloromethane (methyl chloride)	(V)	74-87-3			0 013	H	0 026	I	0 0035	E	
2-Chloronaphthalene	(V)	91-58-7	0 08	I							
2-Chlorophenol	(V)	95-57-8	0 005	I							
Chromium III		16065-83-1	1 5	I							
Chromium VI		18540-29-9	0 003	I			0 00003	H	41	H	
Chrysene		218-01-9			0 0073	E			0 0031	E	0 13
Cobalt		7440-48-4	0 02	E			0 0000057	E			
Copper		7440-50-8	0 04	H							
Cyanide		57-12-5	0 02	I							
4,4-DDD		72-54-8			0 24	I					0 03
4,4-DDE		72-55-9			0 34	I					0 03
4,4-DDT		50-29-3	0 0005	I	0 34	I			0 3395	I	0 03

Table 5.2 Nonradiological Toxicity Constants

Target Analyte List Chemical[1]		CAS Number	Oral RfD (mg/kg-day)		Oral/Ingestion Slope Factor (mg/kg-day)[-1]		Inhalation RfD (mg/kg-day)		Inhalation Slope Factor (mg/kg-day)[-1]		Dermal ABS[2] Fraction Absorbed
Dibenz(a,h)anthracene		53-70-3			7 3	E			3 1	E	0 13
Dibenzofuran		132-64-9	0 004	E							0 1
Dibromochloromethane		124-48-1	0 02	I	0 084	I					0 1
Di-n-butylphthalate		84-74-2	0 1	I							0 1
1,2-Dichlorobenzene (o-)	(V)	95-50-1	0 09	I			0 04	H			
1,4-Dichlorobenzene (p-)	(V)	106-46-7	0 03	E	0 024	H	0 23	I	0 022	E	
3,3-Dichlorobenzidine		91-94-1			0 45	I					0 1
1,1-Dichloroethane	(V)	75-34-3	0 1	H			0 1428571	A			
1,2-Dichloroethane	(V)	107-06-2	0 03	E	0 091	I	0 0014	E	0 091	I	
1,1-Dichloroethene	(V)	75-35-4	0 009	I	0 6	I			0 175	I	
1,2-Dichloroethene (total)	(V)	540-59-0	0 009	H							
2,4-Dichlorophenol (at pH 6 8)		120-83-2	0 003	I							
1,2-Dichloropropane	(V)	78-87-5			0 068	H	0 0011429	I			
cis-1,3-Dichloropropene	(V)	10061-01-5	0 03	Ic	0 1	I	0 0057143	Ic	14	Ic	
trans-1,3-Dichloropropene	(V)	10061-02-6	0 03	Ic	0 1	I	0 0057143	Ic	14	Ic	
Dieldrin		60-57-1	0 00005	I	16	I			16	I	0 1
Diethylphthalate		84-66-2	0 8	I							0 1
2,4-Dimethylphenol	(V)	105-67-9	0 02	I							
Dimethylphthalate		131-11-3	10	W							0 1
4,6-Dinitro-2-methylphenol (4,6-dinitro-o-cresol)	(V)	534-52-1	0 001	E							
2,4-Dinitrophenol		51-28-5	0 002	I							
2,4-Dinitrotoluene		121-14-2	0 002	I	0 68	I					
2,6-Dinitrotoluene		606-20-2	0 001	H	0 68	I					
Di-n-octylphthalate		117-84-0	0 02	H					0 014	E	0 1
Endosulfan I		959-98-8	0 006	I							0 1
Endosulfan II		33213-65-9	0 006	I							0 1
Endosulfan sulfate		1031-07-8	0 006	I							0 1
Endosulfan (technical)		115-29-7	0 006	I							0 1

Table 5.2 Nonradiological Toxicity Constants

Target Analyte List Chemical[1]		CAS Number	Oral RfD (mg/kg-day)		Oral/Ingestion Slope Factor (mg/kg-day)$^{-1}$		Inhalation RfD (mg/kg-day)		Inhalation Slope Factor (mg/kg-day)$^{-1}$		Dermal ABS[2] Fraction Absorbed
Endrin (technical)		72-20-8	0 0003	I							0 1
Ethylbenzene	(V)	100-41-4	0 1	I			0 2857143	I	0 00385	E	
Fluoranthene		206-44-0	0 04	I							0 13
Fluorene	(V)	86-73-7	0 06	I							0 13
Heptachlor		76-44-8	0 0005	I	4 5	I			4 5	I	0 1
Heptachlor epoxide		1024-57-3	0 000013	I	9 1	I			9 1	I	0 1
Hexachlorobenzene		118-74-1	0 0008	I	1 6	I			1 6	I	0 1
Hexachlorobutadiene		87-68-3	0 0002	H	0 078	I			0 078	I	0 1
Hexachlorocyclopentadiene		77-47-4	0 006	I			0 000057	I			0 1
Hexachloroethane		67-72-1	0 001	I	0 014	I			0 014	I	0 1
Indeno(1,2,3-cd)pyrene		193-39-5			0 73	E					0 13
Iron		7439-89-6	0 3	E							
Isophorone		78-59-1	0 2	I	0 00095	I					0 1
Lead		7439-92-1									
Lithium		7439-93-2	0 02	E							
Magnesium		7439-95-4									
Manganese (Nonfood)		7439-96-5	0 02	I			1 429E-05	I			
Mercury (elemental)		7439-97-6					0 000086	I			
Methoxychlor		72-43-5	0 005	I							
Methylene chloride (dichloromethane)	(V)	75-09-2	0 06	I	0 0075	I	0 8571429	H	0 001645	I	
2-Methylnaphthalene	(V)	91-57-6	0 02	E							
4-Methyl-2-pentanone (methyl isobutyl ketone)	(V)	108-10-1	0 08	H			0 0229	H			
2-Methylphenol (o-cresol)		95-48-7	0 05	I							0 1
4-Methylphenol (p-cresol)		106-44-5	0 005	H							0 1
Molybdenum		7439-98-7	0 005	I							
Naphthalene	(V)	91-20-3	0 02	I			0 0009	I			0 1
Nickel (soluble)		7440-02-0	0 02	I							
2-Nitroaniline		88-74-4					0 0000571	H			

Table 5.2 Nonradiological Toxicity Constants

Target Analyte List Chemical[1]		CAS Number	Oral RfD (mg/kg-day)		Oral/Ingestion Slope Factor (mg/kg-day)$^{-1}$		Inhalation RfD (mg/kg-day)		Inhalation Slope Factor (mg/kg-day)$^{-1}$		Dermal ABS[2] Fraction Absorbed
Nitrobenzene	(V)	98-95-3	0 0005	I			0 0004	A			
4-Nitrophenol	(V)	100-02-7	0 008	E							
n-Nitrosodiphenylamine	(V)	86-30-6			0 0049	I					
n-Nitrosodipropylamine		621-64-7			7	I					
Pentachlorophenol		87-86-5	0 03	I	0 12	I					0 25
Phenol		108-95-2	0 6	I							
Pyrene		129-00-0	0 03	I							0 1
Selenium		7782-49-2	0 005	I							
Silver		7440-22-4	0 005	I							
Strontium		7440-24-6	0 6	I							
Styrene	(V)	100-42-5	0 2	I			0 2857143	I			
1,1,2,2-Tetrachloroethane	(V)	79-34-5	0 06	E	0 2	I			0 2	I	
Tetrachloroethene	(V)	127-18-4	0 01	I	0 052	E			0 00203	I	
Tin		7440-31-5	0 6	H							
Toluene	(V)	108-88-3	0 2	I			0 1142857	I			
Toxaphene		8001-35-2			1 1	I		I	1 1		0 1
1,2,4-Trichlorobenzene	(V)	120-82-1	0 01	I			0 0571	H			
1,1,1-Trichloroethane	(V)	71-55-6	0 28	E			0 63	E			
1,1,2-Trichloroethane	(V)	79-00-5	0 004	I	0 057	I			0 056	I	
Trichloroethene	(V)	79-01-6	0 0003	E	0 4	E	0 01	E	0 4	E	
2,4,5-Trichlorophenol		95-95-4	0 1	I							
2,4,6-Trichlorophenol		88-06-2			0 011	I			0 01	I	
Uranium (soluble salts)		No CASN	0 003	I							
Vanadium		7440-62-2	0 007	H							
Vinyl acetate		108-05-4	1	H			0 0571429	I			
Vinyl chloride	(V)	75-01-4	0 003	I	0 72	I	0 028	I	0 0154	I	
Xylene (total)	(V)	1330-20-7	2	I							
Zinc		7440-66-6	0 3	I							

Table 5.2 Nonradiological Toxicity Constants

Target Analyte List Chemical[1]		CAS Number	Oral RfD (mg/kg-day)		Oral/Ingestion Slope Factor (mg/kg-day)$^{-1}$		Inhalation RfD (mg/kg-day)		Inhalation Slope Factor (mg/kg-day)$^{-1}$		Dermal ABS Fraction Absorbed
Nitrate		14797-55-8	1 6	I							
Nitrite		14797-65-0	0 1	I							
Ammonium (as Ammonia)		7664-41-7					0 0286	I			
Fluoride (as fluorine)		7782-41-4	0 06	I							

1 Only those constituents in ALF are included

2 Source EPA 2001b

I = IRIS (EPA 2003) H = HEAST (EPA 2001a) A = HEAST Alternate, W = Withdrawn from IRIS or HEAST,

E = EPA-NCEA provisional value

(V) = Chemicals listed are volatile

a = Values given are for PCBs

b = Values given are for chlordane (CAS No 12789-03-6)

c = Values given are for 1,3-dichloropropene

Table 5.3 Radiological Toxicity Constants*

Target Analyte List Chemical	CAS Number	Oral RfD (mg/kg-day)	Soil Ingestion Oral Slope Factor (Risk/pCi)	Water Ingestion Oral Slope Factor (Risk/pCi)	Food Ingestion Oral Slope Factor (Risk/pCi)	Inhalation Slope Factor (Risk/pCi)	External Slope Factor (Risk/yr/pCi/g)
Am-241	14596-10-2		2 17E-10	1 04E-10	1 34E-10	2 81E-08	2 76E-08
Pu-239	15117-48-3		2 77E-10	1 35E-10	1 74E-10	3 33E-08	2 00E-10
Pu-240	14119-33-6		2 77E-10	1 35E-10	1 74E-10	3 33E-08	6 98E-11
U-233	13968-55-3	3 00E-03	1 6E-10	7 18E-11	9 69E-11	1 16E-08	9 82E-10
U-234	13966-29-5	3 00E-03	1 58E-10	7 07E-11	9 55E-11	1 14E-08	2 52E-10
U-235	15117-96-1	3 00E-03	1 57E-10	6 96E-11	9 44E-11	1 01E-08	5 18E-07
U-235+D	15117-96-1(+D)	3 00E-03	1 63E-10	7 18E-11	9 76E-11	1 01E-08	5 43E-07
U-238	7440-61-1	3 00E-03	1 43E-10	6 4E-11	8 66E-11	9 32E-09	4 99E-11
U-238+D	7440-61-1(+D)	3 00E-03	2 1E-10	8 71E-11	1 21E-10	9 35E-09	1 14E-07

* Values are from HEAST for Radionuclides (EPA 2001a)

Conversely, if chronic daily intakes exceed this threshold level, there is a potential that some adverse noncarcinogenic health effects might be observed in exposed individuals

Tables 5 2 and 5 3 list the current values used for calculation of PRGs These tables will be updated as necessary for the CRA

5.3 Dermal Exposure to Chemicals

Because intake from dermal contact is estimated as an absorbed dose, EPA recommends using oral toxicity factors, adjusted if possible by a gastrointestinal absorption fraction, to evaluate toxic effects from dermal contact with potentially contaminated media (EPA 1989, 1992, 2001b) The oral toxicity factor relates the toxic response to an administered intake dose of contaminant, which may be only partially absorbed by the body When specific gastrointestinal absorption rates are not available, gastrointestinal absorption is assumed to be 100 percent and the unadjusted oral toxicity factor is used to assess the response to dermal absorption Adjustments will be made to the oral toxicity factors in Tables 5 2 and 5 3 for assessing dermal exposures in the CRA The values for the adjusted factors and the rationale will be presented in the CRA

5.4 Identification of Radionuclide Dose Conversion Factors

Dose coefficients will be delineated according to federal guidance (EPA 1988a, 1993) Dose coefficients will be tabulated for the committed effective dose equivalent to tissues of the body per unit activity of inhaled or ingested radionuclides The guidelines were derived to be consistent with current federal radiation protection guidance The guidelines are intended to serve as the basis for setting upper bounds on the inhalation and ingestion of, and submersion in, radioactive materials in the workplace The guidance also includes tables of exposure-to-dose conversion factors for general use in assessing average individual committed doses in any population adequately characterized by "Reference Man" (ICRP 1975)

The dose coefficients for external exposure to radionuclides distributed in air, water, and soil will be tabulated in accordance with Federal Guidance Reports Nos 11 and 12 (EPA 1988a, 1993) The dose coefficients are based on dosimetric methodologies and include the results of calculations of the energy and angular distributions of the radiations incident upon the body and transport of these radiations within the body Particular effort was devoted to expanding the information available for the assessment of the radiation dose from radionuclides distributed on or below the ground surface

Dose coefficients for external exposure relate the doses to organs and tissues to the concentrations of radionuclides in environmental media This is referred to as "external exposure," because the radiations arise outside the body Intakes of radionuclides may also be by inhalation or ingestion, where the radiations are emitted inside the body In either case, the dosimetric quantities of interest are the radiation dose received by the more radiosensitive organs and tissues of the body Radiation of concern for external exposures are those sufficiently penetrating to traverse the overlying tissues of the body and deposit ionizing energy in radiosensitive organs and tissues Penetrating radiations are limited to photons, including bremsstrahlung, and electrons The radiation dose depends on the temporal and spatial distributions of the radionuclide to which a human is exposed The mode considered for the CRA for external exposure is exposure to contamination on or in the ground

56

6.0 HUMAN HEALTH RISK CHARACTERIZATION PERFORMED ON AN EU AND AOC BASIS

Action: Characterize risks for the CRA in three ways

1 An onsite WRW will be assessed based on exposure to COCs developed on the basis of the EUs, as discussed in Section 4 2
2 An onsite WRW will be assessed based on exposure to COCs for AOCs determined by the methods discussed in Section 4 2
3 An onsite WRV will be assessed based on exposure to COCs developed on the basis of the EUs

To characterize risks, the chemical-specific intakes calculated in the exposure assessment are multiplied by the applicable chemical-specific, dose-response factors to compute estimates of the cancer risk for an individual over a lifetime of exposure, or the intakes are compared with RfDs (chronic, subchronic, or acute) for noncarcinogenic health effects The nature, weight-of-evidence, and magnitude of uncertainty for the potential critical health effects are considered The process of quantifying health risks includes the following

- Calculating and characterizing carcinogenic effects for each COC, receptor, pathway, and exposure scenario;
- Calculating and characterizing noncarcinogenic effects for each COC, receptor, pathway, and exposure scenario,
- Calculating and characterizing radiation dose for each radionuclide COC, receptor, pathway, and exposure scenario, and
- Conducting qualitative (or quantitative, if necessary) uncertainty analysis

6.1 Calculating and Characterizing Carcinogenic Effects

The following calculation will be used to determine carcinogenic effects by obtaining numeric estimates (i e , unitless probability) of lifetime cancer risks

$$Risk = Intake \times CSF \qquad \text{(Equation 6-1)}$$

where

Risk = potential lifetime excess cancer risk (unitless probability)

CSF = cancer slope factor ($[mg/kg\text{-}day]^{-1}$ or pCi^{-1})

Intake = chronic daily lifetime intake (mg/kg-day or pCi) from equations in Table 4 7

CSFs will be used as provided in IRIS Inhalation and oral ingestion CSFs are used with their respective inhalation and ingestion intakes to estimate potential carcinogenic health risks The CSFs used are presented and discussed in the toxicity assessment (Section 5 1)

Cancer risks are summed separately across all potential chemical carcinogens and radionuclides considered in the risk assessment using the following equations

$$Risk_{Tc} = \Sigma Risk_{ic} \quad \text{(Equation 6-2)}$$

$$Risk_{Tr} = \Sigma Risk_{ir} \quad \text{(Equation 6-3)}$$

where

$Risk_{Tc}$ = total chemical cancer risk (unitless probability)

$Risk_{ic}$ = risk estimate for the ith chemical contaminant (unitless probability)

$Risk_{Tr}$ = total radionuclide cancer risk (unitless probability)

$Risk_{ir}$ = risk estimate for the ith radionuclide contaminant (unitless probability)

These equations are an approximation of the precise equation for combining risks to account for the probability of the same individual developing cancer as a consequence of exposure to two or more carcinogens The difference between the precise equation and this approximation is negligible for total cancer risks less than 0 1 (10^{-1}) The risk summation assumes independence of action by the compounds (i e , no synergistic or antagonistic actions) The limitations of this approach include conservative risk estimates due to the use of multiple upper-bound estimates of CSFs, increased uncertainty when adding potential carcinogenic risk across weight-of-evidence cancer classes (A through C), and uncertainty due to possible interactions among carcinogens

A table of risks for each exposure scenario will be presented to show contaminant- and pathway-specific risk, with contaminants presented by rows and pathways presented by columns Risks will be subtotaled across pathways for each contaminant

A total carcinogenic risk will also be summed across weight-of-evidence classifications as an aid in the discussion of the uncertainty of the estimates In accordance with EPA guidance, only one significant digit is retained when summarizing calculated risks (EPA 1989)

The CRA is an assessment of the human health and ecological risks from residual contamination The pathways and contaminants driving the risk will be noted and accompanied by a discussion of any qualifying information

In addition to presenting the incremental cancer risks due to contaminants at the Site, perspective may be provided by giving examples of typical background sources of risk, such as for arsenic or uranium The text will note assumptions associated with the calculations, and discuss the importance of background risks associated with each exposure scenario The CRA summary section will present risks for each scenario

6.2 Calculating and Characterizing Noncarcinogenic Effects

Health risks associated with exposure to individual noncarcinogenic compounds are determined by calculating HQs and HIs The noncarcinogenic HQ is the ratio of the intake or exposure level to the RfD, as follows

$$HQ_i = Intake_i/RfD_i \quad \text{(Equation 6-4)}$$

where

HQ_i = noncarcinogenic HQ for i^{th} substance

$Intake_i$ = intake for i^{th} substance (mg/kg-day) for appropriate exposure period

RfD_i = reference dose for i^{th} substance (mg/kg-day) for appropriate exposure duration

Inhalation and oral ingestion RfDs are used with their respective inhalation and ingestion intakes to estimate potential noncarcinogenic health effects Intake and RfD are expressed in the same units and represent the same exposure period The RfDs used are presented and discussed in the toxicity assessment of the CRA COCs that have been determined to have subchronic (two-week to seven-year exposure) or acute (less than two-week exposure) effects in the toxicity assessment will be characterized using subchronic or acute RfDs, or other dose-response information, as available

HIs are the summed HQs for each chemical across an exposure pathway An HI is calculated using the following equation

$$HI_{pw} = \sum HQ_i \qquad \text{(Equation 6-5)}$$

where

HI_{pw} = HI for an exposure pathway (unitless)

HQi = HQ for the ith COC (unitless)

The HI_{pw} values are not statistical probabilities of a potential effect If the HI_{pw} exceeds one, there is a concern for potential noncarcinogenic health effects In general, the greater the HI above one, the greater the level of concern However, the level of concern does not increase linearly as the HI approaches or exceeds one

Noncarcinogenic effects will be presented in the CRA tables similar to those used in the presentation of carcinogenic risk Each table will show contaminant- and pathway-specific effects with contaminants presented in rows, and pathways presented by columns HI_{pw}s will be subtotaled across pathways to develop an HI for the exposure scenario (HI_{es}), if the same individuals would consistently be exposed to more than one pathway for each contaminant

HQ_is approaching or exceeding one will be segregated and summed by mode of action or target organ to calculate the total HI by target organ (HI_{to}) A total HI_{to} will also be summed across all pathways and contaminants for a specific receptor scenario Both of these procedures are subject to limitations One significant digit is retained when summarizing the calculated indices

The CRA will evaluate HQs and HIs that exceed one Factors such as uncertainty inherent in the RfD(s), mode(s) of action, target organ(s), and severity of health effect(s) will be discussed The pathways and contaminants driving the risk will be noted and discussed A summary table presenting HI_{es} subtotals for all scenarios will be created for presentation in the CRA risk summary section This may be presented by placing the results for each scenario in rows, and providing information on HIs, dominant COCs, and dominant pathways in columns

6.3 Dermal Assessment

As discussed in the toxicity assessment (Section 5 0), evaluation and assessment of risks for the dermal route are based on absorbed dose as opposed to the administered dose for other routes The dermally absorbed dose (DAD) must be calculated separately and the toxicity factors adjusted according to estimated gastrointestinal absorption in critical studies The cancer risk or HI is calculated using Equation 6-6

$$Dermal\ cancer\ risk = DAD \times SFabs \qquad \text{(Equation 6-6)}$$

where

DAD = dermally absorbed dose (mg/kg-day)
SFabs = absorbed CSF $(mg/kg\text{-}d)^{-1}$

The noncarcinogenic health hazard is calculated in a similar way

$$Dermal\ cancer\ risk = DAD / RfDabs \qquad \text{(Equation 6-7)}$$

where

DAD = dermally absorbed dose (mg/kg-day)
RfDabs = absorbed RfD (mg/kg-d)

6.4 Calculating and Characterizing Radiation Dose

The following calculation will be used to determine the radiation dose (NCRP 1985)

$$Dose = DCF \times Intake \qquad \text{(Equation 6-8)}$$

where

DCF = dose conversion factor (millirems per picocurie [mrem/pCi] or millirems per picocurie per gram [mrem/pCi/g])
Intake = radionuclide intake or media concentration (pCi or pCi/g)

Inhalation and oral ingestion DCFs are used with their respective inhalation and ingestion intakes to estimate radiation dose For external irradiation, external DCFs are used with their respective soil concentrations to estimate radiation dose DCFs are calculated using mathematical extrapolation models based on human epidemiological studies

Radiation dose is summed separately across all potential radionuclides considered in the dose assessment using the following equation

$$Dose_T = \Sigma Dose_i \qquad \text{(Equation 6-9)}$$

where

$Dose_T$ = total radiation dose, expressed in millirems (mrem)

$Dose_i$ = radiation dose estimate for the ith radionuclide (mrem)

A table of radiation doses for each exposure scenario will be created to show contaminant- and pathway-specific dose, with radionuclides presented by rows and pathways presented by columns Reasonable exposure pathway combinations will be identified and the likelihood that the same individuals would consistently be exposed by more than one pathway will be evaluated In most situations, a receptor could be exposed by several pathways in combination For these situations, doses will be subtotaled across pathways for each radionuclide

In addition to presenting the incremental radiation dose due to radionuclides at the Site, perspective may be provided by giving examples of typical background sources of dose from anthropogenic and terrestrial sources Assumptions associated with the calculations will be noted and discussed The CRA summary section will present doses for each exposure scenario as well as a brief discussion of the uncertainty of the risk estimates

6.5 Conducting an Uncertainty Analysis

The uncertainty analysis characterizes the various sources and their contributions to uncertainty in the CRA These uncertainties are driven by uncertainty in the Site investigation data, likelihood of hypothetical exposure scenarios, transport modes used to estimate concentrations at receptor locations, receptor intake parameters, and toxicity values used to characterize risk Additionally, uncertainties are introduced in the risk assessment when exposures to several substances across multiple pathways are summed

The concept of uncertainty can be more fully defined by distinguishing between variability and knowledge uncertainty Variable parameters are those that reflect heterogeneity in a well-characterized population, for which the distributions would not generally be narrowed through further measurement or study Certain parameters reflect a lack of information about properties that are invariant and whose single, true value could be known exactly by the use of a perfect measuring device Where appropriate, qualitative uncertainty analysis may distinguish between variability and uncertainty This type of uncertainty analysis will identify each key source of uncertainty, present an estimate of the relative impact of the uncertainty on the CRA, and include any clarifying remarks

There are four stages of analysis applied in the risk assessment process that can introduce uncertainties

- Data collection and evaluation,
- Exposure assessment,
- Toxicity assessment, and
- Risk characterization

The discussion of uncertainty is an important component of the risk assessment process Point estimates of risk do not fully convey the range of information considered and used in developing the assessment (EPA 1992) To provide information about the uncertainties associated with the reasonable maximum exposure (RME) estimate, uncertainties identified during the CRA process will be discussed qualitatively In some cases, the effects on risks of the variability in some factors may be calculated to show potential risk ranges

61

7.0 ERA

Scope: Develop and document the methodology for the ERA portion of the CRA

This section provides the methodology for the ERA in support of the CRA The methodology uses existing RFETS ERA methodologies (DOE 1996b, 1996c) and more recent EPA guidance on performing ERAs at Superfund sites (EPA 1997, 1999, 2000a)

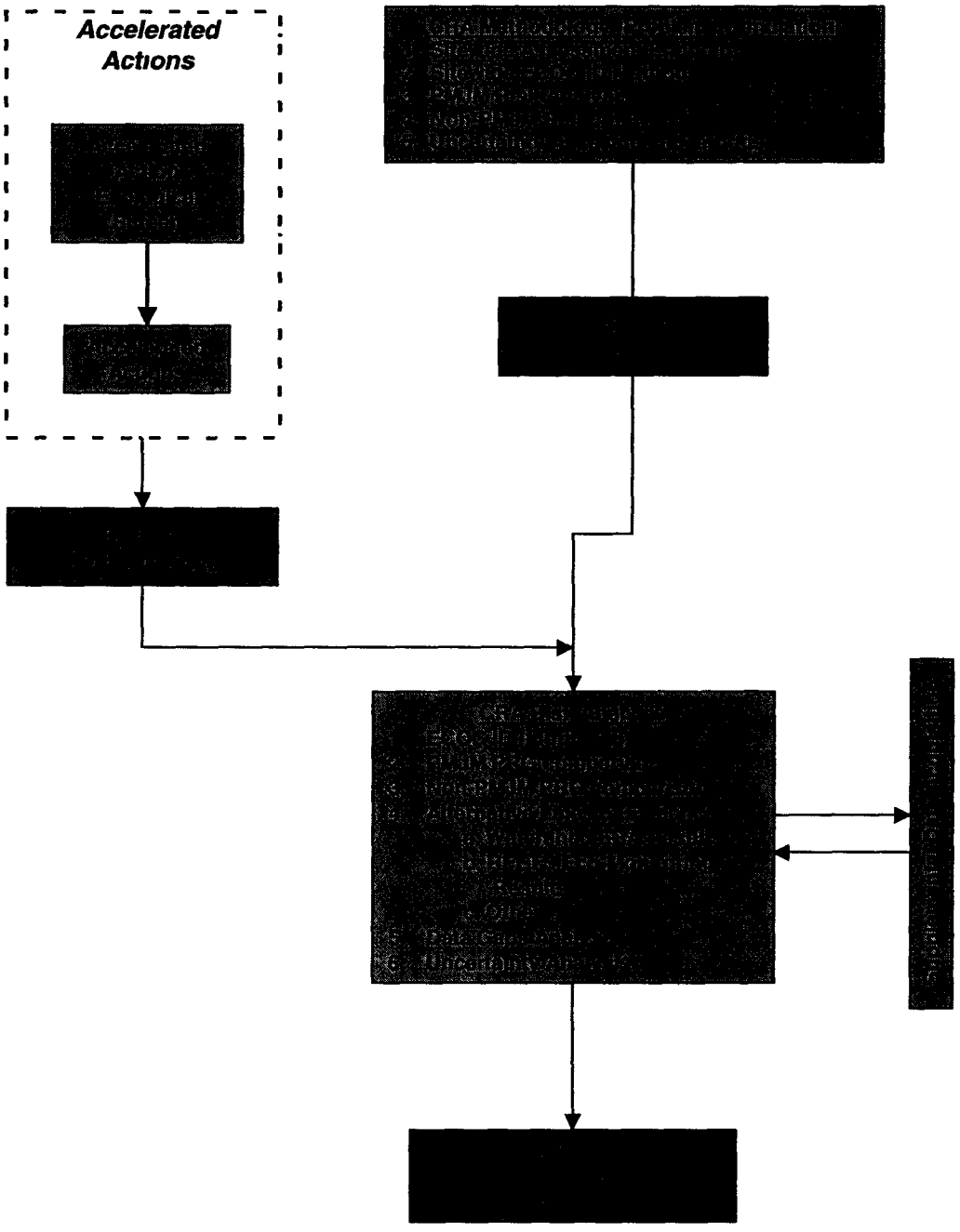
The existing RFETS methodologies were used to perform an ERA for the Woman and Walnut Creek watersheds in the BZ The results were presented in the *Draft Final Phase I RFI/RI Report Appendix N, Woman Creek Priority Drainage Operable Unit No 5* (DOE 1995b) Hereafter, this ERA will be referred to as the Draft Watershed ERA

An ERA has not been performed for areas within the IA Buildings, parking lots, or other developed areas cover much of the IA As a result, the IA does not currently represent a significant ecological resource However, the reasonably anticipated land use for the IA will be a wildlife refuge and an ERA is needed to characterize the potential exposure and ecological risk due to residual contamination in soil or other media

An overview of the ERA process is depicted on Figure 7 1 The ERA analysis is intended to document residual ecological risks after accelerated action The analysis will include two main phases Data on PCOCs in abiotic media from the Site will be compared to ecological PRGs that have been developed for abiotic media and a range of ecological receptor types The analysis will be conducted using all Site data from previous investigations and confirmation sampling from accelerated actions The PRG comparisons will be used to identify receptor of concern (ROC)/PCOC pairs for which PCOC concentrations exceed receptor-appropriate benchmarks, and to map the locations where the PRGs are exceeded

Further analyses will be conducted for areas identified in the above analyses based on additional lines of evidence Results of the Draft Watershed ERA (DOE 1995b) will be reviewed in the context of information that has been developed since that ERA, such as the mapping of Preble's meadow jumping mouse (PMJM) habitat On the basis of this review, data or information gaps will be identified and addressed in the CRA

Figure 7.1 Sequence of Activities for the ERA



63

Best Available Copy

PRGs will be specific to the ROCs and the level of protectiveness needed For ROCs that are not protected by state or federal statute (e g , threatened or endangered species), PRGs will represent exposures equal to the lowest observed adverse effect levels (LOAELs) PRGs for PMJM will be more protective because it is a rare species with legal protection PMJM PRGs will be based on no observed adverse effect levels (NOAELs) PRGs are being developed for the analytes included in RFCA Attachment 5, Table 3 (DOE et al 1996 [as modified])

Data used for the PRG comparison process will be from abiotic media (soil, surface water, and sediment). For accelerated action areas, data will be from confirmation sampling In addition, the ERA may use the results of Sitewide surface water and groundwater transport modeling efforts to predict exposure of aquatic and terrestrial species at points of potential discharge, such as hillside seeps (terrestrial) and streams (terrestrial and aquatic)

7.1 Use of Draft Watershed ERA in CRA

Purpose: The results of the previously completed Draft Watershed ERA will be used to support the current assessment of ecological risks from residual contamination at the Site

Results of the Draft Watershed ERA will be an important line of evidence in the risk analysis process The Draft Watershed ERA represents a comprehensive exposure and risk calculation process conducted specifically for the RFI/RI process at RFETS The results will be used on several levels For example, PRG calculations include assumptions about the extent to which ecological contaminants of concern (ECOCs) are accumulated from abiotic media to biota in the food chain The literature-based bioaccumulation factors (BAFs) used in developing the PRGs are typically conservative and tend to overestimate the ECOC concentrations in forage and prey, which, in turn, tend to overestimate risk BAFs are site-specific and the assumptions used in the PRG calculations may not match the reality at the Site The Draft Watershed ERA contains data on ECOC concentrations in biota throughout the active areas of the Site These data were used in exposure and risk calculations, eliminating the need for the use of BAFs because the actual PCOC concentrations in tissue were available for the exposure calculations Therefore, results of the exposure analyses will be used to determine whether the PRGs are overestimating risk for the Site

Data from the Draft Watershed ERA, RFI/RI reports, or ecological monitoring studies may be used in a data gap analysis to help determine whether additional data are needed to assess risks in specific areas This may be especially applicable to PMJM habitats along the creeks where soil and biota data were collected The results of the Watershed ERA can be used to determine whether additional data are needed to fill spatial data gaps along the drainages Results of ecological monitoring at the Site may be used to help determine whether there is properly functioning habitat in the AOCs

7.2 CRA Background, SCM, and DQOs

Actions: Specify information needed on the physical setting, develop an SCM of ecological receptors and exposure pathways to guide the ERA process, specify risk management goals and assessment endpoints, and develop DQOs to guide the ERA process

7.2.1 Environmental Setting

The description of the environmental setting at RFETS will be presented in Section 2 0 of the RI/FS Report and will include the physical characteristics of the Site, such as topography, geology, and hydrology The types and extent of plant and animal communities present on Site will be discussed in the ERA

After accelerated actions, species diversity, abundance, and habitats may change significantly Therefore, it will be important to determine the following

- Present and future extent of wetlands habitat on Site,
- Sensitive/protected plant species habitat (i e , Ute Ladies'-Tresses) on Site,
- Present and future PMJM habitat locations on Site,
- Other protected or special status species sightings or habitats on Site (e g , bald eagles and peregrine falcons), and
- Vegetation/habitat types to be introduced in the IA

Much of the above information is available from ecological characterization and monitoring activities for the Site Site physical characteristics are well described Surface water and groundwater flow patterns and future Site configuration have been discussed in various reports that address the Sitewide water balance, actinide migration, and land configuration Results of these studies will be used in conjunction with data on nature and extent of contamination, select assessment endpoints, and ECOC screening methodologies to complete the problem formulation phase of the ERA Where data from other studies such as the Draft Watershed ERA are used to make decisions, the specific data on which a conclusion or result will be presented or the location of the original document where the data can be found will be cited

7.2.2 SCM

Development of the SCM is the first step in the problem formulation, or planning, phase of ERAs (EPA 1997) The purpose of the SCM is to help identify environmental stressors and the potential pathways by which ecological receptors may be exposed to them This step allows investigators to identify the potentially complete pathways that will become the focus of the ERA

An SCM for the Draft Watershed ERA was described in the Sitewide Conceptual Model Technical Memorandum (SCMTM) (DOE 1996c) The SCMTM established the relationships among the key components of the RFETS ecosystem and included the following information

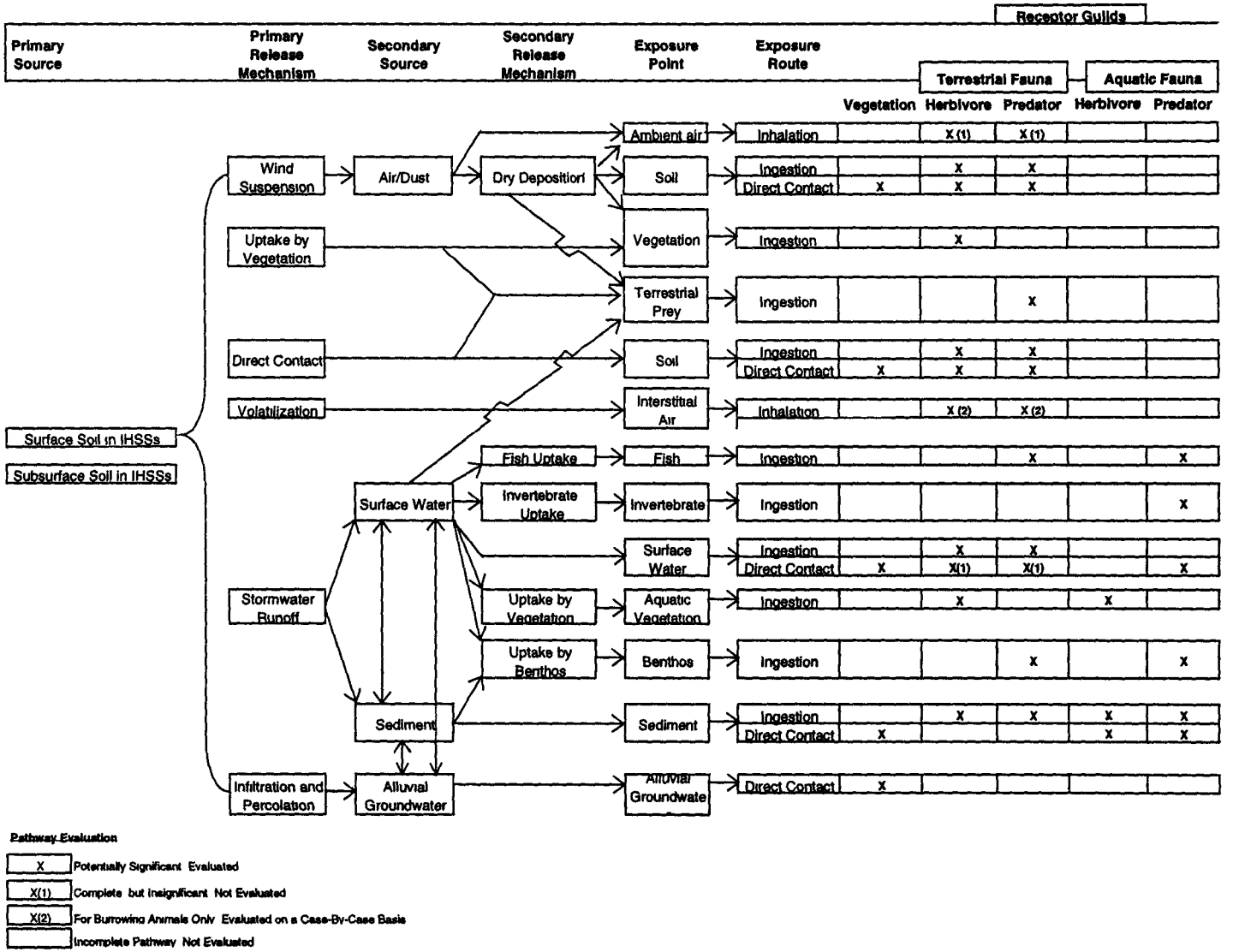
- Description of the environmental setting at RFETS, including the natural physical and biological systems and a brief description of the primary contaminant source areas or IHSSs,
- Description of the important contaminant fate and transport pathways in abiotic media,
- Description of the important exposure pathways, including primary exposure media, exposure points, receptor guilds, and exposure routes,
- Description of receptor guilds and identification of key species in each guild to be used in representative exposure estimates at RFETS,
- Species-specific exposure parameters to be used in estimating exposure to key receptors,
- Measurement endpoints for which data have been collected, and
- A summary of existing environmental data, data sources, and ongoing monitoring programs

The SCM has been updated to reflect the most appropriate ecological receptors for the Site as a wildlife refuge (Figure 7 2) The purpose of the SCM is to help identify potential pathways by which ecological receptors may be exposed to PCOCs The identified pathways become the focus of the ERA The SCM will also be used to identify measurement endpoints for use in evaluation of assessment endpoints (Suter 1993)

- Figure 7 2 identifies several potential pathways that describe how a receptor might contact a PCOC The figure identifies pathways that are probably complete and potentially significant pathways for exposure of the receptor groups Some of the pathways (inhalation and dermal contact with surface water for terrestrial fauna) are designated as potentially complete but insignificant and will not be quantitatively evaluated Inhalation of PCOCs in ambient (surface) air is generally thought to be insignificant compared to ingestion pathways (EPA 2000c) and is generally not evaluated quantitatively in ERAs In addition, there is little information available to assess the potential toxicity of PCOC concentrations in air Therefore, while the pathway may not be significant, it is identified as a source of uncertainty that may result in an underestimate of exposure Dermal exposure to surface water is also thought to be a minor pathway for most terrestrial species at RFETS For metals, polar organic compounds, and radionuclides, the skin, fur, and feathers are generally a significant barrier to absorption Nonpolar organic PCOCs are more likely to be transferred across external surfaces However, the low concentrations at which such compounds are found in surface water and low absorption rates for most terrestrial receptors limit the potential exposures For terrestrial vertebrates at RFETS, oral ingestion is likely to be more significant and "drive" risk rather than either inhalation or dermal contact For some scenarios, such as burrowing animals, dermal pathways may be evaluated for organic PCOCs in surface soils However, the oral pathway is expected to be the most important exposure pathway for PCOCs

Best Available Copy

Figure 7.2 Ecological SCM



Specifically, the ERA will provide the following:

- Description of the important contaminant fate and transport pathways in abiotic and biotic media,
- Description of the important exposure pathways, including primary exposure media, exposure points, receptor guilds, and exposure routes,
- Description of receptor guilds and identification of key species in each guild to be used in representative exposure estimates at RFETS,
- Species-specific exposure parameters to be used in estimating exposure to key receptors, and

Measurement endpoints for which data have been collected

7.2.3 Ecological Risk Management Goals and Assessment Endpoints

In order to focus ERAs, EPA (1997) recommends identifying overall site management goals and assessment endpoints on which the analysis of risk should focus Assessment endpoints are the explicit description of the ecological values to be protected as a result of management actions at a site The overall risk management goal identified for use in developing the ERA for the CRA was

- Site conditions after accelerated actions should not represent significant risk of adverse ecological effects due to exposure to Site-related residual contamination

Significant adverse ecological effects means toxicity that results in reductions in survivorship or reproductive capability that threatens populations or communities at RFETS For relatively rare and legally protected species with small populations, such as PMJM, significant adverse effects can occur even if individuals are affected Therefore, the assessment for PMJM will address the potential for individual mice to be adversely affected by contact with PCOCs For nonprotected species, the assessment will focus on population-level effects where some individuals may suffer adverse effects, but the effects are not ecologically significant because the overall Site population is not affected

For PMJM, the overall risk management goal and assessment endpoints are

- **Goal** Prevent adverse effects on individual PMJM due to lethal, mutagenic, reproductive, systemic, or general toxic effects of contact with PCOCs from the Site
- **Assessment Endpoints** Survival, growth, and reproduction of individual PMJM at the Site

For nonprotected ecological receptors, the risk management goal and assessment endpoints are

- **Goal** Prevent adverse effects on populations due to lethal, mutagenic, reproductive, systemic, or general toxic effects of contact with PCOCs from the Site
- **Assessment Endpoints** Survival, growth, and reproduction adequate to sustain populations at the Site

The nonprotected receptors to be included as assessment endpoints for the Site are shown in Table 7 1 The receptors were identified based on ecological functional groups, then representative species were identified to focus the analysis

Table 7.1 Representative Species for the ERA

Functional Group	Representative Species
Burrowing Small Mammal	Black-tailed Prairie Dog
Herbivorous or Omnivorous Small Mammal	Deer Mouse
Insectivorous Small Mammal	Deer Mouse
Herbivorous or Omnivorous Bird	Mourning Dove
Ruminant Wildlife	Mule Deer
Mammalian Predator	Coyote
Avian Predator	American Kestrel
Plants	General
Aquatic Life	General aquatic life, including amphibians, and benthic macroinvertebrates (sediment exposure)

7.2.4 DQOs

As with the HHRA process, the approach to the ERA is presented in the format of DQOs (EPA 1997)

Step 1: State the Problem

Potentially toxic substances have been released at the Site Ecological receptors could be exposed to the substances To date, ecotoxicological risks have been characterized only for portions of the BZ in the Woman Creek and Walnut Creek watersheds (DOE 1995b)

The problem to be addressed by the ERA is

> *"Site ecological conditions must be assessed after accelerated actions "*

Step 2: Identify the Decision

The ERA will characterize what is known about the exposures, and whether they have resulted, or could result, in significant adverse effects to ecological receptors The overall Site management question to be addressed by the ERA is

> *"Are residual long-term ecological risks from Site-specific contaminants acceptable for the long-term Site use and management goals?"*

In order to address this general decision, additional decisions to be addressed include

- Have the nature and extent of contaminants on the Site been identified with adequate confidence, based on documented Site history (process knowledge), sample distribution and number, and analytical results?
- Is further risk characterization necessary to make risk management decisions related to the ecological risk management goals at the Site?

Step 3: Identify the Inputs to the Decision

Information needed to resolve the ERA decision statements is as follows

- Existing data for areas under consideration,

- Results from a DQA screen (Section 3.1 5) applied for each type of environmental medium as prescribed in this Methodology;
- Results from the DQA screen compared to ecotoxicologically based screening level values,
- Maps for Sitewide PCOCs depicting the distribution of sampling locations with concentrations compared to PRGs,
- Ecological data that have become available since the completion of the previous ERAs (e g , the Integrated Ecological Monitoring program), and
- Data and results from the previous ERAs conducted at RFETS

Step 4: Define the Study Boundaries

Study boundaries are used to determine the areas from which data will be used, and identify where future sampling will occur These study boundaries are listed below

- All available, qualified data will be used The assessment will be confined to the area within the current RFETS boundary unless the onsite assessment indicates circumstances that could alter the conclusions of the assessment performed earlier for OU 3 (DOE 1996a)
- Soil will be assessed generally from the land surface to a depth below ground surface that is consistent with both potential contamination and the depth to which mammals may burrow in the RFETS environment
- The ERA portion of the CRA will consider ECOCs in surface water The results of modeling the transport of groundwater to surface water will be compared to PRGs (i e , State of Colorado water quality standards) for aquatic life Further assessment will be performed for ECOCs passing the PRG screen

Step 5: Develop a Decision Rule

In addition to the decision rules cited for data adequacy in Section 3 0, decision rules that describe how the data will be evaluated for the ERA are listed below

- If maximum concentrations Sitewide are greater than the NOAEL PRGs, then further evaluation is needed
- If the maximum is greater than the PMJM NOAEL PRG and located in PMJM habitat, then the analyte is a PMJM ECOC
- If the 95UCL is greater than the LOAEL PRG or the maximum is three times the LOAEL PRG for the ROC, and the analyte is retained for further analysis after a best professional judgment evaluation (including assessment of detection frequency and comparison to background), the analyte is a non-PMJM ECOC
- Non-PMJM receptors If the ECOC for a non-PMJM ROC in the appropriate habitat has a detection frequency greater than 5 percent or the ECOC presents a specific risk based on best professional judgment (as documented in the CRA), and the 95UCL exceeds the LOAEL PRG or the maximum in the patch is three times the LOAEL PRG, then locations will be mapped and risks will be assessed

- PMJM receptor If the maximum concentration of an ECOC in a PMJM habitat patch exceeds the NOAEL PRG, or is three times the NOAEL PRG, Thiessen polygon mapping will be performed, and habitat patches for further risk analysis will be recommended Decisions on habitat patches for further assessment will be made in consultation with the regulatory agencies

Step 6: Specify Tolerable Limits on Decision Errors

Several sources potentially contribute uncertainty to the CRA Best professional judgment and input from the regulatory agencies is needed for decisions regarding data gaps and risk management actions The rationale and justification will be included in the CRA Report EPCs for nonprotected species are often represented by the 95UCL of the mean for a data population As a screening step for nonprotected species, this metric is compared to a specific PRG. Although not a formal hypothesis test, the implied Type 1 error rate (i e , alpha) for this comparison is 5 percent, because use of the 95UCL implies that the mean exposure is not expected to exceed the metric with more than 5 percent frequency

Step 7: Optimize the Design

Based on the iterative nature of the DQO process, any decision that is not consistent with project goals will result in a reinitiation of the DQO process If determination of the nature and extent of analytes is found to be inadequate, further sampling will be initiated If sampling power is determined to be inadequate for any given scenario and set of analyte data, more samples will be collected and the sampling power will be recalculated

7.2.5 Data Types and Adequacy

The SCM suggests that ecological receptors may be exposed to PCOCs in abiotic and biological media Site data on PCOC concentrations in soil, surface water, and sediment will be evaluated to support the CRA Biological tissue analysis results will not be used in the initial phase of the IA and CRA assessments However, potential uptake of PCOCs into prey and forage species will be considered in development of the PRGs

The IA and BZ SAPs (DOE 2001, 2002b) identify laboratory analytical methods to provide data with adequately low method detection limits (MDLs) and practical quantitation limits (PQLs) to allow meaningful comparison to ecological screening levels in abiotic media PCOC concentrations in soil and sediment will be expressed as "total recoverable" (e g , sample prepared for analysis by EPA Method 3050 or equivalent) PCOC concentrations in surface water will be appropriately compared to water quality standards for protection of aquatic life Surface water data used to assess risks to wildlife drinking the surface water will be based on "total recoverable" (i e , unfiltered) analyses Data on PCOC concentrations in biological tissue were collected for the Draft Watershed ERA and associated studies These data may also be used in a weight-of-evidence approach to risk analysis after soil screening has been conducted Data V&V will be conducted as for the HHR process described in Section 3 1 5

In addition to the comparison of PRGs directly to analytical data, models may be used to estimate PCOC concentrations in stormwater runoff from potentially contaminated soil and groundwater that may surface at seeps or in streams Both sources of water could contact aquatic biota or wildlife

Adhering to the specifications of the DQOs as outlined above will ensure the adequacy of data for use in the ERA In addition, the DQA will help ensure that the quality of data is consistent with RFETS standards

7.2.6 Ecological PRGs

As noted above, the CRA will be based on an assessment procedure similar to that adopted for assessment of human health risk in the accelerated action process PRGs for wildlife will be developed based primarily on potential ingestion of ECOCs in abiotic media, forage, and prey, and the transfer of ECOCs among these exposure points The specific methodology for developing PRGs will be presented under separate cover for regulatory agency review The following is an overview of the processes intended for each of the environmental media

Soil

EPA's ecological soil screening levels (EcoSSLs) (EPA 2000c) process was used as a general guidance for developing the PRGs Acquisition of primary literature, followed by extensive review and scoring of the documents was not done Instead, extensive use was made of existing databases and compilations of ecotoxicity information, especially those from other DOE facilities, such as Oak Ridge National Laboratory (ORNL) (ORNL 1994)

Both NOAEL- and LOAEL-based PRGs will be developed for small mammals, ground-feeding birds, terrestrial invertebrates, and avian predators The complete PRG development process is included in Appendix N of Appendix 3 of RFCA (DOE et al 1996 [as modified]) PRGs will be developed for a list of the Sitewide PCOCs listed in Attachment 5, Table 3 of RFCA (DOE et al 1996 [as modified]), and potentially for several PCOCs that have been detected at the Site but are not included in Attachment 5

Sediments

For sediments, sediment quality values (SQVs) have been developed for many chemicals and are available from several sources SQVs are generally expressed as concentration terms and, therefore, require no calculations or assumptions However, the assumptions underlying the development of SQVs will be evaluated to determine consistency with uses at RFETS

Surface Water

For surface water, ecotoxicologically based water quality criteria are available from several sources For assessment of risk to aquatic receptors, only criteria appropriate for selected onsite receptors will be used As a screening step, PRGs will be taken from State of Colorado water quality standards, federal Ambient Water Quality Criteria (AWQC), and other databases such as that from ORNL If concentrations from onsite sampling locations exceed AWQCs, then samples from downstream locations may be needed to assess risk in areas affected from flow from the sampled areas

Radionuclides

Soil benchmarks for radionuclides were developed for RFETS during the Draft Watershed ERA (Higley and Kuperman 1994) Since then, DOE's Biological Dose Assessment Committee has developed additional procedures for assessing exposure and risk to terrestrial

and aquatic biota (DOE 2002c) These additional processes will be used to verify protectiveness of the earlier soil benchmarks, and evaluate protectiveness of available surface water criteria

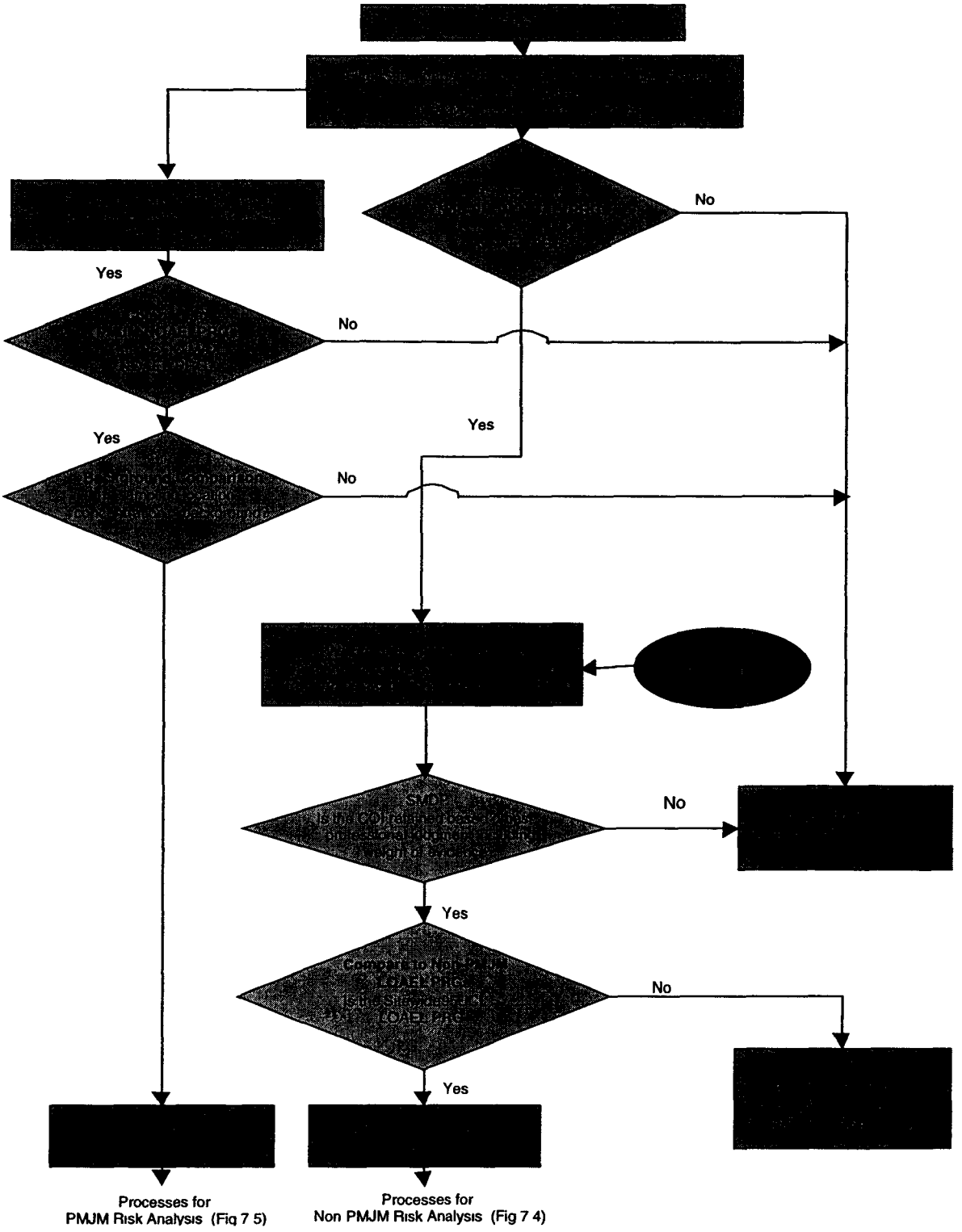
7.3 Sitewide ECOC Identification Process

Action: Identify ECOCs for the ERA.

A comprehensive list of Sitewide ECOCs will be developed for the CRA based on data representing conditions after accelerated actions PCOCs identified in RFCA Attachment 5, Table 3 (DOE et al 1996 [as modified]) will form the starting point for the ECOC identification process shown on Figure 7 3 In addition, the Sitewide database will be screened to identify the maximum detected concentrations of analytes not included in Attachment 5, Table 3 The PCOC screen will then include maximum concentrations for potentially toxic analytes (i e , analytes that are not nutrients such as calcium, potassium, and sodium)

The entire Sitewide database will be queried, filtered by media, and subjected to a DQA screen (Section 3 1 5) to identify which data meet the needs of the DQOs discussed in the previous section Following the DQA screen, two data sets will be created One will include all Sitewide data, the other will include only sampling locations in PMJM habitat For each data set, "U-" qualified nondetects will have one-half the reported result concentration substituted, basic descriptive statistics will then be calculated, such as number of samples, percent detections, maximum detections, mean detection, standard deviation, variance, and so forth

Figure 7.3 Sitewide ECOC Screening Process



74 Best Available Copy

Soil data in each data set will be compared to NOAEL-based PRGs If the maximum detected concentration of the PCOC does not exceed the NOAEL-based PRG, the PCOC will be dropped from further analysis in the CRA and the rationale for removing it from further analysis will be recorded and presented in the CRA Report If the maximum detected PCOC concentration in the PMJM habitat data set exceeds the NOAEL-based PRG, it will be retained as an ECOC for the PMJM

PCOCs that have detected concentrations greater than the NOAEL-based PRG in the Sitewide data set will undergo further analyses to determine their status as ECOCs If the PCOC was detected in less than 5 percent of the samples, the PCOC will be evaluated using best professional judgment as to its potential to cause risk to wildlife receptors at the Site This decision, or scientific management decision point (SMDP), will be made in cooperation with regulatory agency personnel The determination will consider process knowledge and spatial and temporal factors, as well as the physical and chemical properties of the PCOC as they pertain to the potential for risk to the wildlife receptors at the Site If it is determined that no potential risk is expected, the PCOC will be dropped from further analysis and the rationale for the decision will be documented in the CRA Report The radionuclide and metal PCOCs passing the 5 percent screen will then be statistically compared to background concentrations, as appropriate, using the methods discussed in Section 4 4 8

For those PCOCs that remain, LOAEL-based PRGs will be compared with the Sitewide 95UCL concentrations Any PCOC with a 95UCL concentration below the PRG will be dropped from further analysis in the CRA for non-PMJM habitat Otherwise, the PCOC will be carried forward as a Sitewide ECOC in the non-PMJM risk analysis in the CRA

The output from the Sitewide ECOC screen will be a list of ECOCs for analysis of PMJM habitat and list of ECOCs for nonprotected species at the Site The ECOCs identified in these lists will be carried on to the risk analysis processes described in the following section All steps in the analysis will be documented in the CRA Report

7.4 Risk Analysis Process

Action: Assess risks for the PMJM in its habitat areas and other receptors in appropriate areas Sitewide

The following sections describe the process for conducting the ecological risk analysis in the CRA for the Site Two separate analyses will be used in the CRA depending on the status of the habitat designation The risk analysis process for those areas defined as non-PMJM habitat is presented in Section 7 4 2, while the risk analysis process for the PMJM habitat area is presented in Section 7 4 3

7.4.1 EUs

Except for the coyote and mule deer, exposures to ecological receptors will be calculated based on the EUs described for human health (Figure 4 1) Coyote and mule deer are wide-ranging species that generally utilize areas larger than the EUs and will be addressed using

75

Sitewide data The EUs are reasonable aggregations of common source areas, hydrological systems, and habitat for assessing ecological risk.

For non-PMJM receptors, data from within each EU will be aggregated to calculate the 95UCL for use in exposure calculations (Section 7 4.2) For PMJM, sampling locations within PMJM habitat in each EU will be evaluated separately (Section 7 4 3)

7.4.2 Risk Analysis Process for Non-PMJM Receptors

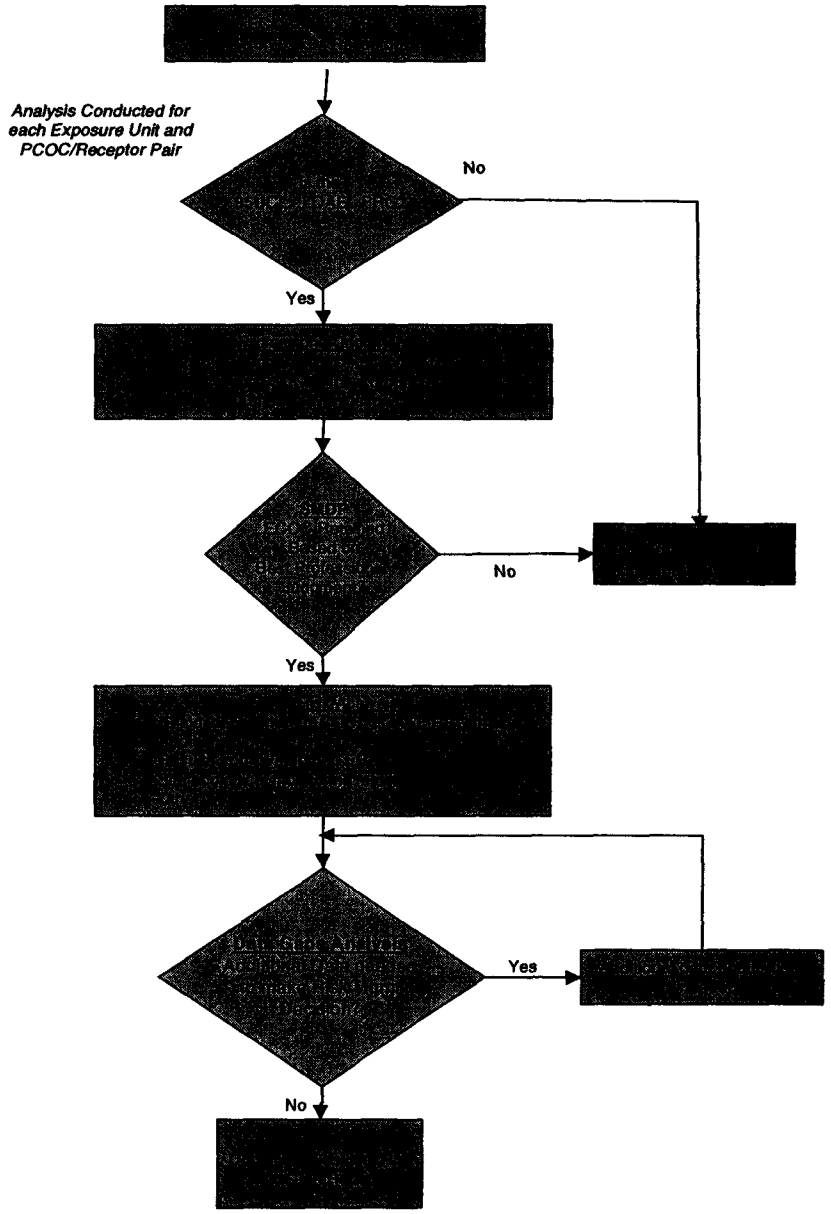
Risk analysis will be conducted in the CRA, following the procedures shown on Figure 7 4, for those ECOCs identified in the screening process described in Section 7 3 for non-PMJM receptors

The analyses described in this section apply to all nonprotected species The analysis will be conducted separately for each receptor, based on data on ECOC concentrations in abiotic media from habitats appropriate for each receptor Data will be aggregated as described above from Sitewide samples and appropriate 95UCLs will be calculated In addition, summary statistics will be calculated including percent detections, mean, standard deviation, and variance for each EU For those ECOCs detected in 5 percent or more of sampling locations in the receptor's habitat, further risk analysis for non-PMJM receptors will be conducted The ECOCs that are detected in less than 5 percent of samples in the receptor's habitat will be evaluated based on process knowledge, spatial and temporal factors, chemical properties (i e , does the ECOC bioaccumulate in food webs), and toxicological properties using a best professional judgment approach for their potential to cause risk to wildlife receptors If it is determined that no potential for risk exists, the ECOC will be recommended for no further ecological risk analysis and the rationale for the recommendation will be provided in the CRA Report

For those ECOCs that are not eliminated based on frequency of detection, or retained based on a professional judgment decision, the 95UCL for the EU (or Sitewide for wide-ranging receptors) will be compared to the LOAEL-based PRG This comparison will be conducted for each of the ROCs Those ECOCs for which the 95UCL exceeds the comparison value will be dropped from further risk analysis The rationale for the decision to drop an ECOC will be presented in the CRA Report

The ECOCs for which representative concentrations exceed the LOAEL PRG will be mapped using Geographic Information Systems (GIS) technology to show the locations where concentrations of the ECOC exceed both NOAEL- and LOAEL-based PRGs As added information, maps will also show locations that exceed three times the LOAEL PRG to help identify the relatively most affected areas Concentrations at each location will be compared to RFETS background to determine whether the Site represents incremental risk If so, then analysis of the risks will be conducted using additional lines of evidence, such as Site ecological monitoring studies, Draft Watershed ERA results, or other applicable sources to determine whether other data suggest risk

Figure 7.4 CRA Risk Analysis Process for the Non-PMJM Receptor



An analysis of potential data gaps will be conducted for ECOCs that represent significant risk If additional data are deemed to be necessary to reduce the uncertainty in the risk analysis to an acceptable level, steps will be taken to identify the types of data that may be necessary and plans to collect the additional data will be made

Each ECOC evaluated in the risk analysis for non-PMJM habitat will be incorporated into the risk characterization portion of the CRA (Section 7 4 4) A detailed evaluation of the uncertainties involved in the risk characterization will also be included in the CRA Report

77 ailable Copy

For exposure scenarios directed at surface soil, data from no deeper than 6 inches will be used Surface soil samples in the database include a variety of depth intervals (e g., surface scrape, 0 to 2 inches, 0 to 6 inches) Whenever available, the depth intervals for surface soil data will be documented for each location to help interpret risk

Subsurface soil data are also available for a variety of depth intervals Whenever available, the depth intervals from which the data were collected will be specified when assessing subsurface exposures This information can be used to help determine whether contaminants at depth represent risks to burrowing species

7.4.3 Risk Analysis Process for PMJM Receptor

ECOCs identified for the PMJM receptor (Figure 7 3) will be subjected to a more conservative risk analysis process than those identified in the non-PMJM habitats due to the regulatory status of the PMJM Section 7 3 discusses the process to be used to determine the list of ECOCs to be inlcuded in the risk analysis for the PMJM The process for the risk analysis for PMJM is shown on Figure 7 5

The EUs and PMJM habitat are illustrated on Figure 7 6 For each ECOC identified for risk analysis in the PMJM habitats in each EU, maps will be prepared to identify the sampling locations in PMJM habitat for which ECOC concentrations exceed the NOAEL-based PRGs and locations that exceed three times the NOAEL-based PRGs Thiessen polygon mapping techniques will be employed to visualize the areas of potential risk to the PMJM These maps will aid in the identification of habitat patches that will be recommended for further assessment Concentrations will be compared to RFETS background concentrations to determine whether the location represents additional risk above natural conditions

These maps will be reviewed with the appropriate regulatory agencies for input on further risk analysis activities The major goal of the first agency input step is to identify patches of habitat that can be used to aggregate data into groupings that could reasonably be expected to represent home ranges of individual PMJM Aggregated data will be used to calculate upper-bound exposure concentrations (95UCL)

Based on regulatory agency input and best professional judgment, decisions regarding the acceptability of risk levels for the PMJM will be made A binary decision point of acceptable or unacceptable levels of risk will be the outcome of the risk analysis process for the PMJM habitat The rationale and justification will be documented in the CRA Report Additional data may also be collected if data gaps are evident A detailed evaluation of potential data gaps will be provided prior to the determination of the potential for risk The results of this decision point and the uncertainties associated with the potential risk to the PMJM will be discussed in detail in the CRA

7.4.4 Ecological Risk Characterization and Uncertainty

This section describes risk characterization for ecological receptors and sources of uncertainty

Risk Characterization

The risk analysis in the previous sections describes the process for analysis of risk data and presentation of results As noted above, the analysis for the CRA compares data from abiotic

media to chemical- and receptor-specific PRGs Analyses based on results of the Draft Watershed ERA will also be used to provide additional site-specific information

Characterization of risk will focus on the overall results for each assessment endpoint The overall risk will be summarized for each receptor group and level of biological organization (i e , individual- or population-level of protection), as appropriate for the assessment endpoints As noted by EPA (1997), a well-balanced risk characterization should " .present risk conclusions and information regarding the strengths and limitations of the assessment for other risk assessors, EPA decision-makers, and the public "

Risk characterization has two main components the risk estimation and the risk description The risk estimation will summarize results of the analysis, identifying the receptors and ECOCs for which abiotic concentrations exceeded PRGs, and the locations at which they were exceeded The risk description will then provide context for the analysis, including the proportions of Sitewide habitats that are affected and interpretation of overall results including data from the Draft Watershed ERA The risk description will also include overall risk conclusions for each assessment endpoint

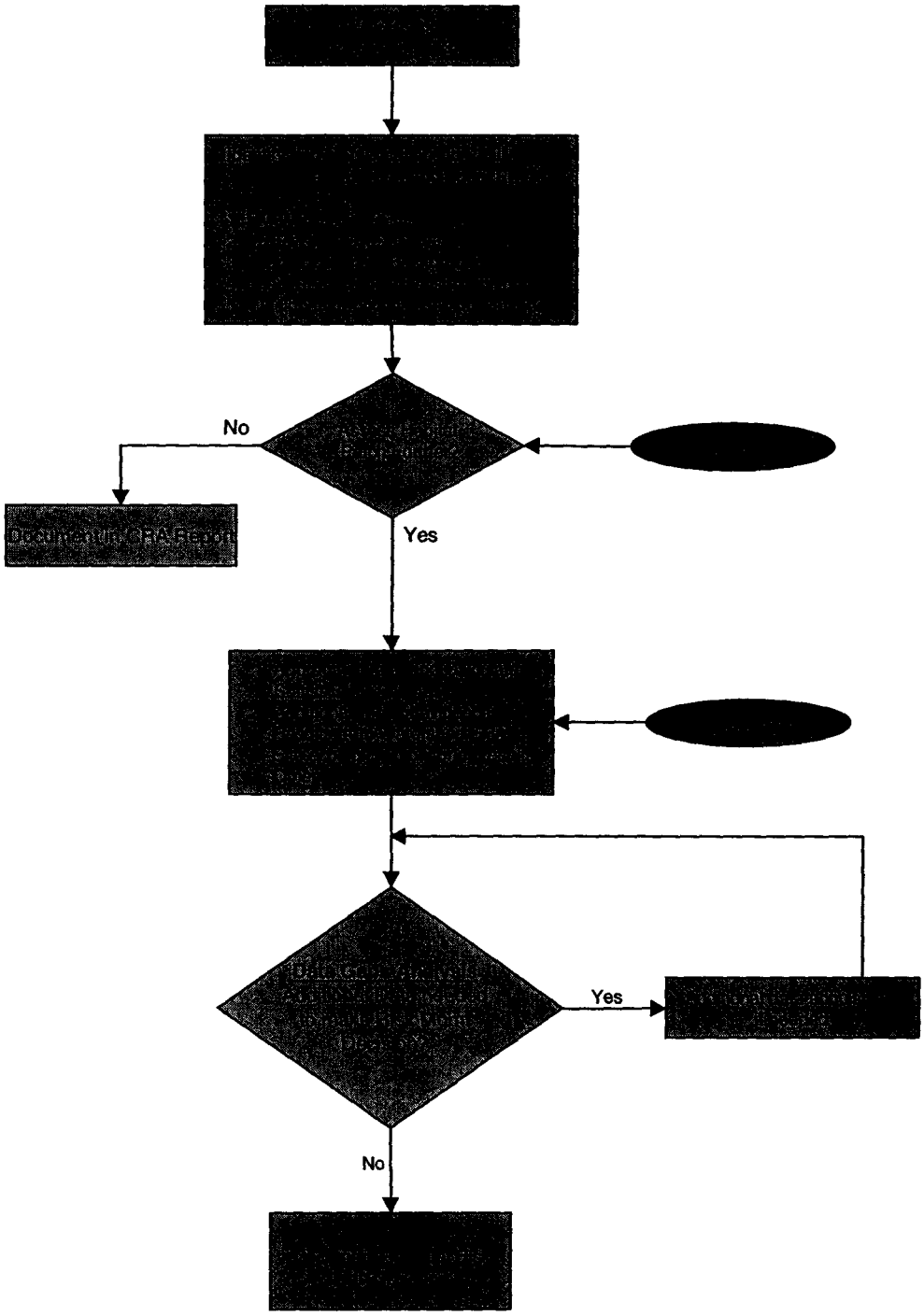
Uncertainty

The objective of the uncertainty analysis for the ERA is to identify and characterize the sources of uncertainty, and the potential effects on conclusions of the CRA The uncertainty analysis will also identify the methods by which uncertainty for various sources were accounted for in the analysis These uncertainties are driven by uncertainty in the Site investigation data, likelihood of hypothetical exposure scenarios, transport modes used to estimate concentrations at receptor locations, receptor intake parameters, and toxicity values used to characterize risk

Sources of uncertainty can be related to systematic and natural variability and to chemical and physical knowledge Variable parameters are those that reflect heterogeneity in a well-characterized population, for which the distributions would not generally be narrowed through further measurement or study Certain parameters reflect a lack of information about the behavior or toxicity of chemicals in the system The uncertainty analysis for the ERA will be largely qualitative, identifying the primary sources and ranking their potential importance Quantitative estimates of uncertainty are incorporated through estimate of variability in data

Uncertainty will be summarized for the primary components from which different kinds of uncertainty derive sources of variability (i e , natural and systematic) in data, exposure assessment parameters, uncertainty about ECOC toxicity thresholds, and the overall risk characterization

Figure 7.5 CRA Risk Analysis Process for the PMJM Receptor



Best Available Copy

THIS TARGET SHEET REPRESENTS AN
OVER-SIZED MAP / PLATE FOR THIS DOCUMENT:
(Ref: 03-RF-01471; JLB-094-03)

Draft Final Comprehensive Risk Assessment Work Plan and Methodology

September 2003

Figure 7.6:

Preble's Meadow Jumping Mouse Habitat with Exposure Units

September 4, 2003

CERCLA Administrative Record Document, SW-A-004835

U S DEPARTEMENT OF ENERGY
ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE

GOLDEN, COLORADO

81

8.0 CRA REPORT ORGANIZATION

The CRA Report will contain two volumes the HHRA and the ERA Summaries of the HHRA and ERA will be included in the RI/FS text The full assessments with supporting documentation will be attached to the RF/FS report as appendices

The HHRA will contain the following sections

Executive Summary,

Section 1 0 Introduction,

Section 2 0 Site Description,

Section 3 0 Data Quality Assessment and Adequacy,

Section 4 0 COC Identification,

Section 5 0 Exposure Assessment,

Section 6 0 Toxicity Assessment,

Section 7 0 Risk Characterization and Uncertainty Analysis,

Section 8 0 Summary, and

Section 9 0 References

The ERA will contain the following sections

Section 1 0 Introduction/Problem Statement,

Section 2 0 Conceptual Model and Assessment Endpoints,

Section 3 0 Data Quality Assessment and Adequacy,

Section 4 0 Risk Characterization and Uncertainty Analysis,

Section 5 0 Summary, and

Section 6 0 References

Appendices for the reports will be combined to reduce redundancy and will include the following

Data Summary - This appendix will present data used in both the HHRA and ERA reports

828

8.1 Schedule

The schedule for completion of the CRA is presented in Table 8 1

Table 8 1 Completion Schedule for the Draft CRA

Task	Description	Dependencies	Deliverable	Completion Date
Complete CRA Work Plan and Methodology (Methodology)	The Methodology guides performance of the CRA It describes the exposure scenarios and pathways, EUs, DQOS, and exposure assessment methods	The Methodology has ties to the IA and BZ SAPs, primarily for data DQOs that must be consistent This is especially the case for ecological considerations where DQOs for the CRA and accelerated actions are being developed Agency concurrence on the CRA and ecological accelerated action DQOs must be obtained before the SAP modifications can be completed	Draft Final CRA Work Plan and Methodology	September 2003
Develop PRGs for ecological receptor	NOAEL and LOAEL PRGs are being developed for the analytes listed on Table 3 of Attachment 5 of RFCA NOAEL PRGs will apply to PMJM and the lowest LOAEL PRG for other receptors as a group will be used for decision making	Performance of the ERA as well as remedial actions, depends on completion of the PRGs	Draft Ecological PRG Report	October 2003
Perform data gap analysis	Existing data will be analyzed spatially and statistically to determine whether additional data are required to support the CRA This also includes comparison of groundwater concentrations to surface water PRGs to determine whether modeling of groundwater will be required	Completion of the data gap analysis is required to support completion of the Draft CRA If the data gap analysis shows that additional sampling is required, an addendum to the IA or BZ SAPs will be developed to support a sampling effort during the spring and summer of 2004	Draft Data Gap Analysis Report	January 2004
Develop a draft annotated outline of the Draft CRA	The outline will follow the format included in the Draft CRA Methodology It will describe, in brief form, information that will be included in the Draft CRA	Subsequent input to the Draft CRA will conform to the annotated outline	Draft CRA Annotated Outline	January 2004

Table 8.1 Completion Schedule for the Draft CRA

Task	Description	Dependencies	Deliverable	Completion Date
Complete HHRA of one EU and associated regions of concern (AOCs)	It is assumed that sufficient data currently exist to perform a complete human health assessment of one of the EUs on the western side of RFETS It is possible but not certain yet that sufficient data also exist to perform an ecological assessment If data are sufficient, an ecological assessment will be included	The data gap analysis will confirm whether sufficient data exist for both the human health and ecological assessments	Draft risk assessment of one EU, and any associated AOCs	March 2004
Complete HHRA for two additional EUs, including AOCs	It is assumed that there is a high probability that 2 additional EUs currently have sufficient data to perform a human health risk assessment Data sufficiency is not certain for ecological receptors	The data gap analysis is required to confirm data adequacy for both human health and ecological receptors	Draft risk assessment of two EUs and any associated AOCs	June 2004
Complete human health assessment for remaining EUs, including regions of concern (AOCs)	Additional EUs will be made available for review as they are completed	All accelerated actions must be completed in the OU, data gap analysis is complete and confirms data adequacy for both human health and ecological receptors	Draft risk assessments of remaining EUs and associated AOCs	July 2004 – June 2005
Complete the Draft CRA	This includes the complete analysis of ecological and human health risk for all EUs from contamination remaining following remedial actions The assessment will be performed progressively with interim deliverables to be determined but sufficient that the agencies can review analyses prior to issuance of the Draft CRA	Completion of the Draft CRA requires analysis of the human health and ecological exposure pathways across all EUs Also, remediation and confirmation sampling needs to be completed to the extent determined adequate by DOE	Draft CRA	September 2005

9.0 REFERENCES

Crump, K S , H A Guess, and K. L Deal, 1977, "Confidence intervals and tests of hypotheses concerning dose response relations inferred from animal carcinogenicity data", *Biometrics*, Vol 33, pp 437-451

DOE, 1993, Background Geochemical Characterization Report, U S Department of Energy, Rocky Flats Plant, September

DOE, 1995a, Final Geochemical Characterization of Background Surface Soils Background Soils Characterization Program, U S Department of Energy, Rocky Flats Environmental Technology Site, Golden, Colorado, May

DOE, 1995b, Draft Final Phase I RFI/RI Report, Woman Creek Priority Drainage Operable Unit No 5, U S Department of Energy, Rocky Flats Environmental Technology Site, Golden, Colorado, Appendix N, October

DOE, 1996a, Final RFI/RI Report, OU 3 Offsite Areas, U S Department of Energy, Rocky Flats Environmental Technology Site, Golden, Colorado, June

DOE, 1996b, Final Ecological Risk Assessment Methodology Technical Memorandum Ecological Chemicals of Concern (ECOCs) Screening Methodology, U S Department of Energy, Rocky Flats Environmental Technology Site, Golden, Colorado, June

DOE, 1996c, Final Ecological Risk Assessment Methodology Technical Memorandum Sitewide Conceptual Model, U S Department of Energy, Rocky Flats Environmental Technology Site, Golden, Colorado, June

DOE, 1997, Corrective Action Decision/Record of Decision, Operable Unit 3, The Offsite Areas, Rocky Flats Environmental Technology Site, Golden, Colorado, April

DOE, 2000, Draft Comprehensive Risk Assessment Methodology, Rocky Flats Environmental Technology Site, Golden Colorado, September

DOE, 2001, Industrial Area Sampling and Analysis Plan, Rocky Flats Environmental Technology Site, Golden, Colorado

DOE, 2002a, Final Work Plan for the Development of the Remedial Investigation and Feasibility Study Report, Kaiser-Hill Company, L L C , Golden, Colorado, March

DOE, 2002b, Final Buffer Zone Sampling and Analysis Plan, Rocky Flats Environmental Technology Site, Golden, Colorado

DOE, 2002c, A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota (DOE-STD-1153-2002)

DOE, 2003, Final Human Health Risk Assessment for the Solar Evaporation Ponds at the Rocky Flats Environmental Technology Site, Golden, Colorado, February

DOE, EPA, and CDPHE, 1996, Rocky Flats Cleanup Agreement, Joint Agreement between the U S Department of Energy, U S Environmental Protection Agency, Colorado Department of Public Health and Environment, and the State of Colorado, July 19

85

EPA, 1988, Federal Guidance Document No 11, Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion, Office of Radiation Programs, EPA/520/1-88/020, U S Environmental Protection Agency, Washington, D C

EPA, 1989, Risk Assessment Guidance for Superfund, Volume I Human Health Evaluation Manual (Part A), EPA 154011-891002, Office of Emergency and Remedial Response, U S Environmental Protection Agency, Washington, D C

EPA, 1992, Guidelines for Exposure Assessment, Federal Register, Vol 57, No 104, U S Environmental Protection Agency, Washington, D C , May.

EPA, 1993, Federal Guidance Document No 12, External Exposure to Radionuclides in Air, Water, and Soil, EPA-402-R-93-081, U S Environmental Protection Agency, Washington, D C , September

EPA, 1994, Test Methods for Evaluating Solid Waste, Physical/Chemical Methods (SW-846), September

EPA, 1997, Ecological Risk Assessment for Superfund Process for Designing and Conducting Ecological Risk Assessments, Interim Final, U S Environmental Protection Agency, Washington, D C, July

EPA, 1999, Screening Level Ecological Risk Assessment Protocol For Hazardous Waste Combustion Facilities, Peer Review Draft, Office of Solid Waste and Emergency Response, U S Environmental Protection Agency, Washington, D C

EPA, 2000a, Guidance for the Data Quality Objectives Process, EPA QA/G-4, EPA/600/R-96/055, Office of Environmental Information, U S Environmental Protection Agency, Washington, D C , August

EPA, 2000b, Guidance for Data Quality Assessment Practical Methods for Data Analysis, QA/G-9, EPA/600-R-96/084, U S Environmental Protection Agency, Washington, D C, September

EPA, 2000c, Ecological Soil Screening Level Guidance (Draft), Office of Emergency and Remedial Response, July

EPA, 2001a, Health Effects Assessment Summary Tables (HEAST) for Radionuclides, U S Environmental Protection Agency, Washington, D C

EPA, 2001b, Risk Assessment Guidance for Superfund Volume I Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment), Interim, EPA/540/R99/005, OSWER 9285 7-02EP, PB99-963312, September

EPA, 2002a, Calculating Upper Confidence Limits for Exposure Point Concentrations at Hazardous Waste Sites, OSWER 9285 6-10, U S Environmental Protection Agency, Washington, D C , December

EPA, 2002b, Guidance for Comparing Background and Chemical Concentrations in Soil for CERCLA Sites, EPA 540-R-01-003, OSWER 9285 7-41, U S Environmental Protection Agency, Washington, D C , September

EPA, 2003, Integrated Risk Information System, Online Database, Office of Research and Development, U S. Environmental Protection Agency, Cincinnati, Ohio

EPA, CDPHE, and DOE, 2002, Task 3 Report and Appendices Calculation of Surface Radionuclide Soil Action Levels for Plutonium, Americium, and Uranium, Rocky Flats Environmental Technology Site, September

Gilbert, R O , 1987, *Statistical Methods for Environmental Pollution Monitoring*, New York Van Nostrand Reinhold

Higley, K , and R Kuperman, 1995, Radiological Benchmarks for Wildlife at Rocky Flats Environmental Technology Site, March

ICRP, 1975, Report on the Task Group on Reference Man, International Commission on Radiological Protection, Publication 23

Jefferson County, 1996, Data provided by Jefferson County Department of Open Space from surveys performed in 1996, Jefferson County, Colorado

NAS, 2000, Dietary Reference Intake Series 1997-2001, Subcommittees on Upper Reference Levels of Nutrients and Interpretation and Uses of DRIs, Standing Committee on the Scientific Evaluation of Dietary Reference Intakes, Food and Nutrition Board Upper Limits (ULs) developed from RDI by the U S Food and Drug Administration

NAS, 2002, Dietary Reference Intakes for Vitamin A, Vitamin K, Arsenic, Boron, Chromium, Copper, Iodine, Iron, Manganese, Molybdenum, Nickel, Silicon, Vanadium, and Zinc (800 pp), Panel on Micronutrients, Subcommittees on Upper Reference Levels of Nutrients and of Interpretation and Use of Dietary Reference Intakes, and the Standing Committee on the Scientific Evaluation of Dietary Reference Intakes

NCRP, 1985, General Concepts for the Dosimetry of Internally Deposited Radionuclides, National Council on Radiation Protection and Measurement, NCRP Report

NRC, 1997, Multi-Agency Radiological Survey and Site Investigation Manual (MARSSIM) Report, Nuclear Regulatory Commission

ORNL, 1994, Toxicological Benchmarks for Screening Contaminants of Potential Concern, 1994 Revision, Oak Ridge National Laboratory.

Suter, G W , II, ed , 1993, *Ecological Risk Assessment*, Boca Raton Lewis Publishers

USFWS, 2003, Rocky Flats Wildlife Refuge Planning Update, Volume 3, Spring

Appendix A

88A

TABLE OF CONTENTS

1 0 Introduction . 1
1 1 Subsurface Soil Screening-Level PRGs 1
1 1 1 PRG Parameters 2
1 1 2 PRG Equations 2
1 1 3 Subsurface Soil Screening Level PRG Values 3
1 2 Surface Water Screening-Level PRGs 6
1 2 1 PRG Parameters 7
1 2 2 PRG Equations 7
1 2 3 Surface Water Screening Level PRG Values 7
1 3 Subsurface Soil PRGs From Volatilization 11
1 3 1 PRG Parameters and Equations 11
1 3 2 Subsurface Soil Volatilization Screening-Level PRG Values 11
1 4 Groundwater Screening-Level PRGs From Volatilization 15
1 4 1 PRG Parameters & Equations 15
1 4 2 Groundwater Screening Level PRG Values 16

LIST OF TABLES

Table 1 1 PRG Parameters for Subsurface Soil Screen 2
Table 1 2 Subsurface Soil Screening Level PRG Values 3
Table 1 3 PRG Parameters for Surface Water Screen 7
Table 1 4 Surface Water Screening-Level PRG Values 7
Table 1 5 Subsurface Soil Volatilization Screening-Level PRG Values 11
Table 1 6 Groundwater Volatilization Screening Level PRG Values . . 16

ACRONYMS

AOC	area of concern
cm^2	square centimeter
COC	contaminant of concern
CRA	Comprehensive Risk Assessment
EU	exposure unit
g/mg	grams per milligram
hr	hour
HQ	hazard quotient
IGD	Implementation Guidance Document
kg	kilogram
kg/mg	kilograms per milligram
kg/m^3	kilograms per cubic meter
L/day	liters per day
µg/L	micrograms per liter
m^3/day	cubic meters per day
m^3/hr	cubic meters per hour
m^3/kg	cubic meters per kilogram
mg/cm^2	milligrams per square centimeter
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
pCi	picocurie
pCi/g	picocuries per gram
pCi/L	picocuries per liter
PRG	preliminary remediation goal
RBC	risk-based concentration
RFCA	Rocky Flats Cleanup Agreement
RFETS or Site	Rocky Flats Environmental Technology Site
VF	volatilization factor
WRW	wildlife refuge worker
yr	year

89

1.0 INTRODUCTION

The preliminary remediation goals (PRGs) for surface soil presented in the Rocky Flats Cleanup Agreement (RFCA) Appendix N of Appendix 3, Implementation Guidance Document (IGD) (DOE et al 1996 [as modified]), will be used in the Draft Comprehensive Risk Assessment (CRA) for the Rocky Flats Environmental Technology Site (RFETS or Site) Health-based screening-level PRGs are also being developed for this purpose The screening-level PRGs are being developed for organics, inorganics, and radionuclides in subsurface soil, as well as surface water and groundwater (volatilization pathway) These PRGs will support the derivation of chemicals of concern (COCs) at exposure units (EUs) and areas of concern (AOCs) for the CRA The PRGs will also support an analysis of the exposure pathways associated with the wildlife refuge worker (WRW) Specifically, the following sets of PRGs are being developed

- The PRGs for organics, inorganics, and radionuclides in surface soil using the WRW exposure scenario will be used as presented in RFCA, IGD, Appendix N The PRGs are based on the ingestion, inhalation, and external exposure from surface soil These PRGs will support the development of surface soil COCs at EUs and AOCs

- Screening-level PRGs are being developed for organics, inorganics, and radionuclides in subsurface soil using the WRW exposure scenario The PRGs are based on the ingestion, inhalation, and external exposure from subsurface soil These PRGs will support the development of subsurface soil COCs at EUs and AOCs

- Screening-level PRGs are being developed for organics, inorganics, and radionuclides in surface water using the WRW exposure scenario The PRGs are based on the ingestion of surface water These PRGs will support an assessment of the surface water ingestion pathway, including groundwater contributions

- Screening-level PRGs are being developed for volatile organics in subsurface soil and groundwater using the WRW exposure scenario The PRGs being derived are based on the inhalation of volatile organics from subsurface soil and groundwater These PRGs will support an assessment of volatile organics in subsurface soil and groundwater

The following sections further discuss the derivation of the screening-level PRGs, along with the applicable exposure parameters, PRG equations, and PRG values The screening-level PRGs were derived using these PRG equations with the applicable PRG parameters A description of the derivation of the surface soil PRGs is presented in RFCA, IGD, Appendix N Toxicity factors, including inhalation and ingestion slope factors and reference doses, are also found in Appendix N

1.1 Subsurface Soil Screening-Level PRGs

The WRW subsurface soil exposure scenario consists of the following pathways ingestion of surface soil, inhalation of dust (outdoors), and dermal contact for non-radionuclides for a WRW working at the Site for an average of 18 7 years, spending 20 days per year, 4 hours per day exposed to subsurface soil Inhalation of volatiles is not

assessed The external radiation exposure pathway is also included for radionuclides The scenario assumes the worker will be performing soil contact-intensive activities This scenario includes all complete and significant exposure pathways and parameter assumptions that were evaluated in the Task 3 Report and Appendices Calculation of Surface Radionuclide Soil Action Levels for Plutonium, Americium, and Uranium (EPA et al 2002) PRGs were calculated for both 1 x 10^{-6} risk and a hazard quotient (HQ) of 0 1 The more conservative of the two values is chosen for the PRG

1.1.1 PRG Parameters

The PRG parameters listed in Table 1 1 are used to derive PRGs using the PRG equations listed in Section 1 1 2

Table 1.1
PRG Parameters for Subsurface Soil Screen

Exposure Parameter	Variable	Unit	Value/Source
Target hazard index - 1	THI-1	--	0 1
Target excess lifetime cancer risk - 1	TR-1	--	1E-06
Adult body weight	BWa	kg	70
Averaging time - noncarcinogenic	ATnc	yr	18 7
Averaging time - carcinogenic	ATc	yr	70
Exposure frequency	EFwsubs	day/yr	20
Exposure duration	EDw	yr	18 7
Exposure time-outdoors	ETo_w	hr/day	4
Hourly inhalation rate (adult worker)	IRaw	m^3/hr	1 30
Mass loading, (PM10) for inhalation	MLF	kg/m^3	6 7 E-8
Site-specific PEF based on ML	PEF	m^3/kg	14925373
Soil ingestion rate	IRwss	mg/day	100
Exposure time fraction, outdoor	ETFo_w	--	1
Exposure time fraction, indoor	ETFi_w	--	0
WRW skin-soil adherence factor	AFw	mg/cm^2-event	0 117
Event frequency	EVw	events/day	1
WRW skin surface area	SAw	cm^2	3300
Dermal absorption fraction	ABS	--	chemical-specific
Gamma shielding factor (1-Se)	GSF	--	0
Area correction factor	ACF	--	0 9
Oral reference dose	RfDo	mg/kg-day	chemical-specific
Oral cancer slope factor	CSFo	(mg/kg-day) $^{-1}$	chemical-specific
Inhalation reference dose	RfDi	mg/kg-day	chemical-specific
Inhalation cancer slope factor	CSFi	(mg/kg-day) $^{-1}$	chemical-specific
Oral Soil cancer slope factor – radionuclides	CSFsoil	risk/pCi	radionuclide-specific
External cancer slope factor – radionuclides	CSFe	risk/yr/pCi/g	radionuclide-specific

1.1.2 PRG Equations

The following PRG equations are used to derive the PRG values

Noncarcinogenic PRG =

((THI x ATnc(yr) x 365(day/yr)) / (IRwss(mg/day) x EFwsubs(day/yr) x EDw(yr) x 10-6(kg/mg) x 1/RfDo(mg/kg-day) x 1/BWa(kg))) + (IRaw(m^3/hr) x EFwsubs(day/year) x EDw(yy) x ETo_w(hr/day) x 1/PEF*(m^3/kg) x 1/RfDi(mg/kg-day) x 1/BWa(kg) x (ETFo_w + (ETFi_w))) + (SAw(cm^2) x AFw(mg/cm^2-event) x EFwsubs(day/yr) x EDw(yr) x ABS x EVw(events/day) x 1/RfDo(mg/kgd) x 10-6(kg/mg) x 1/BWa(kg))

91

Carcinogenic PRG =

((TR x ATc(yr) x 365(day/yr)) / (IRwss(mg/day) x EFwsubs(day/yr) x EDw(yr) x 10-6(kg/mg) x CSFo(risk/mg/kg-day) x 1/BWa(kg))) + (IRaw(m^3/hr) x EFwsubs(day/yr) x EDw(yr) x ETo_w(hr/day) x 1/PEF*(m^3/kg) x CSFi(risk/mg/kg-day) x 1/BWa(kg) x (ETFo_w + (ETFi_w))) + (SAw(cm^2) x AFw(mg/cm^2 event) x EFwsubs(day/yr) x EDw(yr) x ABS x EVw(events/day) x CSFo(risk/mg/kg-day) x 10-6(kg/mg) x 1/BWa(kg))

Radionuclide Carcinogenic PRG =

(TR / (IRwss(mg/day) x CSFsoil(risk/pCi) x 10^{-3}(g/mg) x EFwsubs(day/yr) x EDw(yr)) + (IRaw(m^3/hr) x 1/PEF(m^3/kg) x CSFi(risk/pCi) x 1000(g/kg) x EFwsubs(day/yr) x EDw(yr) x ETo_w(hr/day) x (ETFo_w + ETFi_w))) + (CSFe(risk/yr/pCi/g) x EF_wsubs(day/yr)/365(day/yr) x ETo_w(hr/day)/24 x ED_w(yr) x ACF)

1.1.3 Subsurface Soil Screening Level PRG Values

Table 1 2 presents Subsurface Soil Screening Level PRG Values

Table 1.2
Subsurface Soil Screening Level PRG Values

Target Analyte	CAS Number	Wildlife Refuge Worker	Wildlife Refuge Worker	Wildlife Refuge Worker
		Noncarcinogenic Subsoil RBC HQ = 0.1 (mg/kg)	**Carcinogenic Subsoil RBC Risk = 1E-06 (mg/kg)**	**Subsurface Soil Risk = 1E-06 or HQ = 0 1 (mg/kg)**
Acenaphthene	83-32-9	5 10E+04		5 10E+04
Acetone	67-64-1	1 28E+05		1 28E+05
Aldrin	309-00-2	2 76E+01	2 02E+00	2 02E+00
Aluminum	7429-90-5	2 85E+05		2 85E+05
Anthracene	120-12-7	2 55E+05		2 55E+05
Antimony	7440-36-0	5 11E+02		5 11E+02
Aroclor 1016	12674-11-2	5 80E+01	4 42E+02	5 80E+01
Aroclor 1221	11104-28-2		1 55E+01	1 55E+01
Aroclor 1232	11141-16-5		1 55E+01	1 55E+01
Aroclor 1242	53469-21-9		1 55E+01	1 55E+01
Aroclor 1248	12672-29-6		1 55E+01	1 55E+01
Aroclor 1254	11097-69-1	1 66E+01	1 55E+01	1 55E+01
Aroclor 1260	11096-82-5		1 55E+01	1 55E+01
Arsenic	7440-38-2	3 43E+02	2 77E+01	2 77E+01
Barium	7440-39-3	3 30E+04		3 30E+04
Benzene	71-43-2	4 26E+02	2 57E+02	2 57E+02
alpha-BHC	319-84-6		6 56E+00	6 56E+00
beta-BHC	319-85-7		2 29E+01	2 29E+01
delta-BHC	319-86-8			
gamma-BHC (Lindane)	58-89-9	3 32E+02	3 19E+01	3 19E+01
Benzo(a)anthracene	56-55-3		4 36E+01	4 36E+01
Benzo(a)pyrene	50-32-8		4 36E+00	4 36E+00
Benzo(b)fluoranthene	205-99-2		4 36E+01	4 36E+01
Benzo(k)fluoranthene	207-08-9		4 36E+02	4 36E+02

Table 1.2
Subsurface Soil Screening Level PRG Values

Target Analyte	CAS Number	Noncarcinogenic Subsoil RBC HQ = 0 1 (mg/kg)	Carcinogenic Subsoil RBC Risk = 1E-06 (mg/kg)	Subsurface Soil Risk = 1E-06 or HQ = 0.1 (mg/kg)
Benzoic Acid (at pH 7)	65-85-0	5 11E+06		5 11E+06
Benzyl Alcohol	100-51-6	3 83E+05		3 83E+05
Beryllium	7440-41-7	1 15E+03	1 63E+03	1 15E+03
bis(2-chloroethyl)ether	111-44-4		4 35E+01	4 35E+01
bis(2-chloroisopropyl)ether	39638-32-9	5 11E+04	6 83E+02	6 83E+02
bis(2-ethylhexyl)phthalate	117-81-7	1 84E+04	2 46E+03	2 46E+03
Bromodichloromethane	75-27-4	2 56E+04	7 71E+02	7 71E+02
Bromoform	75-25-2	2 56E+04	4 66E+03	4 66E+03
Bromomethane (methyl bromide)	74-83-9	2 41E+02		2 41E+02
2-Butanone (methyl ethyl ketone)	78-93-3	2 41E+05		2 41E+05
Butylbenzylphthalate	85-68-7	1 84E+05		1 84E+05
Cadmium (water)	7440-43-9	6 39E+02	2 18E+03	6 39E+02
Cadmium (food)	7440-43-9	1 20E+03	2 18E+03	1 20E+03
Carbon disulfide	75-15-0	1 88E+04		1 88E+04
Carbon tetrachloride	56-23-5	1 02E+02	1 03E+02	1 02E+02
alpha-Chlordane	5103-71-9	5 49E+02	1 18E+02	1 18E+02
beta-Chlordane	5103-74-2	5 49E+02	1 18E+02	1 18E+02
gamma-Chlordane	12789-03-6	5 49E+02	1 18E+02	1 18E+02
4-Chloroaniline	106-47-8	3 69E+03		3 69E+03
Chlorobenzene	108-90-7	7 61E+03		7 61E+03
Chloroethane (ethyl chloride)	75-00-3	1 11E+05	1 65E+04	1 65E+04
Chloroform	67-66-3	2 40E+01	1 30E+02	2 40E+01
Chloromethane (methyl chloride)	74-87-3	1 29E+03	4 64E+02	4 64E+02
2-Chloronaphthalene	91-58-7	1 02E+05		1 02E+05
2-Chlorophenol	95-57-8	6 39E+03		6 39E+03
Chromium III	16065-83-1	1 92E+06		1 92E+06
Chromium VI	18540-29-9	2 84E+03	3 35E+02	3 35E+02
Chrysene	218-01-9		4 36E+03	4 36E+03
Cobalt	7440-48-4	1 93E+03		1 93E+03
Copper	7440-50-8	5 11E+04		5 11E+04
Cyanide	57-12-5	2 56E+04		2 56E+04
4,4-DDD	72-54-8		1 79E+02	1 79E+02
4,4-DDE	72-55-9		1 26E+02	1 26E+02
4,4-DDT	50-29-3	5 72E+02	1 26E+02	1 26E+02
Dibenz(a,h)anthracene	53-70-3		4 36E+00	4 36E+00
Dibenzofuran	132-64-9	3 69E+03		3 69E+03
Dibromochloromethane	124-48-1	1 84E+04	4 11E+02	4 11E+02
Di-n-butylphthalate	84-74-2	9 22E+04		9 22E+04
1,2-Dichlorobenzene (o-)	95-50-1	3 90E+04		3 90E+04
1,4-Dichlorobenzene (p-)	106-46-7	3 40E+04	1 05E+03	1 05E+03
3,3-Dichlorobenzidine	91-94-1		7 67E+01	7 67E+01
1,1-Dichloroethane	75-34-3	2 81E+04		2 81E+04
1,2-Dichloroethane	107-06-2	5 93E+02	1 32E+02	1 32E+02
1,1-Dichloroethene	75-35-4	1 15E+04	2 13E+01	2 13E+01
1,2-Dichloroethene (total)	540-59-0	1 15E+04		1 15E+04
2,4-Dichlorophenol (at pH 6 8)	120-83-2	3 83E+03		3 83E+03
1,2-Dichloropropane	78-87-5	4 32E+02	7 03E+02	4 32E+02
cis-1,3-Dichloropropene	10061-01-5	1 22E+04	8 21E+00	8 21E+00

Table 1.2
Subsurface Soil Screening Level PRG Values

Target Analyte	CAS Number	Noncarcinogenic Subsoil RBC HQ = 0 1 (mg/kg)	Carcinogenic Subsoil RBC Risk = 1E-06 (mg/kg)	Subsurface Soil Risk = 1E-06 or HQ = 0.1 (mg/kg)
trans-1,3-Dichloropropene	10061-02-6	1 22E+04	8 21E+00	8 21E+00
Dieldrin	60-57-1	4 61E+01	2 15E+00	2 15E+00
Diethylphthalate	84-66-2	7 37E+05		7 37E+05
2,4-Dimethylphenol	105-67-9	2 56E+04		2 56E+04
Dimethylphthalate	131-11-3	9 22E+06		9 22E+06
4,6-Dinitro-2-methylphenol (4,6-dinitro-o-cresol)	534-52-1	1 28E+03		1 28E+03
2,4-Dinitrophenol	51-28-5	2 56E+03		2 56E+03
2,4-Dinitrotoluene	121-14-2	2 56E+03	7 03E+01	7 03E+01
2,6-Dinitrotoluene	606-20-2	1 28E+03	7 03E+01	7 03E+01
Di-n-octylphthalate	117-84-0	1 84E+04	9 80E+05	1 84E+04
Endosulfan I	959-98-8	5 53E+03		5 53E+03
Endosulfan II	33213-65-9	5 53E+03		5 53E+03
Endosulfan sulfate	1031-07-8	5 53E+03		5 53E+03
Endosulfan (technical)	115-29-7	5 53E+03		5 53E+03
Endrin (technical)	72-20-8	2 76E+02		2 76E+02
Ethylbenzene	100-41-4	7 02E+04	5 31E+03	5 31E+03
Fluoranthene	206-44-0	3 40E+04		3 40E+04
Fluorene	86-73-7	5 10E+04		5 10E+04
Heptachlor	76-44-8	4 61E+02	7 65E+00	7 65E+00
Heptachlor epoxide	1024-57-3	1 20E+01	3 78E+00	3 78E+00
Hexachlorobenzene	118-74-1	7 37E+02	2 15E+01	2 15E+01
Hexachlorobutadiene	87-68-3	1 84E+02	4 41E+02	1 84E+02
Hexachlorocyclopentadiene	77-47-4	4 37E+03		4 37E+03
Hexachloroethane	67-72-1	9 22E+02	2 46E+03	9 22E+02
Indeno(1,2,3-cd)pyrene	193-39-5		4 36E+01	4 36E+01
Iron	7439-89-6	3 83E+05		3 83E+05
Isophorone	78-59-1	1 84E+05	3 63E+04	3 63E+04
Lead	7439-92-1			
Lithium	7439-93-2	2 56E+04		2 56E+04
Magnesium	7439-95-4			
Manganese (nonfood)	7439-96-5	4 35E+03		4 35E+03
Mercury (elemental)	7439-97-6	3 15E+04		3 15E+04
Methoxychlor	72-43-5	6 39E+03		6 39E+03
Methylene chloride (dichloromethane)	75-09-2	5 79E+04	3 16E+03	3 16E+03
2-Methylnaphthalene	91-57-6	2 56E+04		2 56E+04
4-Methyl-2-pentanone (methyl isobutyl ketone)	108-10-1	2 05E+04		2 05E+04
2-Methylphenol (o-cresol)	95-48-7	4 61E+04		4 61E+04
4-Methylphenol (p-cresol)	106-44-5	4 61E+03		4 61E+03
Molybdenum	7439-98-7	6 39E+03		6 39E+03
Naphthalene	91-20-3	3 87E+03		3 87E+03
Nickel (soluble)	7440-02-0	2 56E+04		2 56E+04
2-Nitroaniline	88-74-4	2 09E+04		2 09E+04
Nitrobenzene	98-95-3	4 15E+02		4 15E+02
4-Nitrophenol	100-02-7	1 02E+04		1 02E+04
n-Nitrosodiphenylamine	86-30-6		9 76E+03	9 76E+03

Table 1.2
Subsurface Soil Screening Level PRG Values

Target Analyte	CAS Number	Noncarcinogenic Subsoil RBC HQ = 0 1 (mg/kg)	Carcinogenic Subsoil RBC Risk = 1E-06 (mg/kg)	Subsurface Soil Risk = 1E-06 or HQ = 0 1 (mg/kg)
n-Nitrosodipropylamine	621-64-7		6 83E+00	6 83E+00
Pentachlorophenol	87-86-5	1 95E+04	2 03E+02	2 03E+02
Phenol	108-95-2	7 67E+05		7 67E+05
Pyrene	129-00-0	2 76E+04		2 76E+04
Selenium	7782-49-2	6 39E+03		6 39E+03
Silver	7440-22-4	6 39E+03		6 39E+03
Strontium	7440-24-6	7 67E+05		7 67E+05
Styrene	100-42-5	1 54E+05		1 54E+05
1,1,2,2-Tetrachloroethane	79-34-5	7 67E+04	1 25E+02	1 25E+02
Tetrachloroethene	127-18-4	1 28E+04	7 68E+02	7 68E+02
Tin	7440-31-5	7 67E+05		7 67E+05
Toluene	108-88-3	3 91E+04		3 91E+04
Toxaphene	8001-35-2		3 13E+01	3 13E+01
1,2,4-Trichlorobenzene	120-82-1	1 15E+04		1 15E+04
1,1,1-Trichloroethane	71-55-6	9 97E+04		9 97E+04
1,1,2-Trichloroethane	79-00-5	5 11E+03	2 95E+02	2 95E+02
Trichloroethene	79-01-6	3 43E+02	2 45E+01	2 45E+01
2,4,5-Trichlorophenol	95-95-4	1 28E+05		1 28E+05
2,4,6-Trichlorophenol	88-06-2		4 33E+03	4 33E+03
Uranium (soluble salts)	No CASN	3 83E+03		3 83E+03
Vanadium	7440-62-2	8 94E+03		8 94E+03
Vinyl acetate	108-05-4	1 20E+06		1 20E+06
Vinyl chloride	75-01-4	1 56E+03	5 15E+01	5 15E+01
Xylene (total)	1330-20-7	2 56E+06		2 56E+06
Zinc	7440-66-6	3 83E+05		3 83E+05
Nitrate	14797-55-8	2 04E+06		2 04E+06
Nitrite	14797-65-0	1 28E+05		1 28E+05
Ammonium (as Ammonia)	7664-41-7	1 05E+07		1 05E+07
Fluoride (as fluorine)	7782-41-4	7 67E+04		7 67E+04
		pCi/g	pCi/g	pCi/g
Am-241	14596-10-2		6 24E+01	6 24E+01
Pu-239	15117-48-3		6 79E+01	6 79E+01
Pu-240	14119-33-6		6 80E+01	6 80E+01
U-233	13968-55-3	3 83E+03	1 31E+02	1 31E+02
U-234	13966-29-5	3 83E+03	1 35E+02	1 35E+02
U-235	15117-96-1	3 83E+03	1 15E+01	1 15E+01
U-235+D	15117-96-1(+D)	3 83E+03	1 10E+01	1 10E+01
U-238	7440-61-1	3 83E+03	1 52E+02	1 52E+02
U-238+D	7440-61-1(+D)	3 83E+03	3 76E+01	3 76E+01

1.2 Surface Water Screening-Level PRGs

The WRW surface water exposure scenario consists of the following pathway ingestion of surface water on the Site for 18 7 years This scenario was not considered to be a significant exposure pathway in the Task 3 Report and Appendices Calculation of Surface Radionuclide Soil Action Levels for Plutonium, Americium, and Uranium (EPA

95

et al 2002) Calculations in this appendix were performed deterministically PRGs were calculated for both a 1 x 10^{-6} risk and an HQ of 0 1

1.2.1 PRG Parameters

The PRG parameters presented in Table 1 3 were used to derive PRGs using the PRG equations listed in Section 1 2 2

Table 1.3
PRG Parameters for Surface Water Screen

Exposure Parameter	Variable	Unit	Default
Target hazard index-1	THI-1	--	0 1
Target excess lifetime cancer risk-1	TR-1	--	1E-06
Adult body weight	BWa	kg	70
Averaging time - noncarcinogenic	ATnc	yr	18 7
Averaging time - carcinogenic	ATc	yr	70
Exposure frequency - Surface water	EFwsw	day/yr	42
Exposure duration	EDw	yr	18 7
Surface water incidental ingestion rate	IRsw	L/day	0 03
Oral reference dose	RfDo	mg/kg-day	chemical-specific
Oral cancer slope factor	CSFo	risk/(mg/kg-day)	chemical-specific
Water ingestion slope factor – radionulides	CSFSw	risk/pCi	radionuclide-specific

1.2.2 PRG Equations

The following PRG equations are used to derive the PRG values

Noncarcinogenic PRG =

((THI x ATnc(yr) x 365(day/yr))/(IRsw(L/day) x EFwsw(day/yr) x EDw(yr) x 1/RfDo(mg/kg-day) x 1/BWa(kg)))

Carcinogenic PRG =

((TR x ATc(yr) x 365(day/yr))/(IRsw(L/day) x EFwsw(day/yr) x EDw(yr) x CSFo(risk/mg/kg-day) x (1/BWa(kg)))

Radionuclide Carcinogenic PRG =

(TR/(IRsw(L/day) x EFwsw(day/yr) x EDw(yr) x CSFw (risk/pCi))

1.2.3 Surface Water Screening Level PRG Values

Table 1 4 presents the surface water screening level PRG values

Table 1.4
Surface Water Screening-Level PRG Values

Target Analyte	CAS Number	Wildlife Refuge Worker	Wildlife Refuge Worker	Wildlife Refuge Worker
		Noncarcinogenic Surface Water HQ = 0 1 (mg/L)	Carcinogenic Surface Water Risk = 1E-06 (mg/L)	Surface Water Risk = 1E-06 or HQ = 0 1 (mg/L)
Acenaphthene	83-32-9	1 22E+02		1 22E+02
Acetone	67-64-1	2 03E+02		2 03E+02

96

Table 1.4
Surface Water Screening-Level PRG Values

Target Analyte	CAS Number	Noncarcinogenic Surface Water HQ = 0 1 (mg/L)	Carcinogenic Surface Water Risk = 1E-06 (mg/L)	Surface Water Risk = 1E-06 or HQ = 0 1 (mg/L)
Aldrin	309-00-2	6 08E-02	4 47E-03	4 47E-03
Aluminum	7429-90-5	2 03E+03		2 03E+03
Anthracene	120-12-7	6 08E+02		6 08E+02
Antimony	7440-36-0	8 11E-01		8 11E-01
Aroclor 1016	12674-11-2	1 42E-01	1 08E+00	1 42E-01
Aroclor 1221	11104-28-2		3 80E-02	3 80E-02
Aroclor 1232	11141-16-5		3 80E-02	3 80E-02
Aroclor 1242	53469-21-9		3 80E-02	3 80E-02
Aroclor 1248	12672-29-6		3 80E-02	3 80E-02
Aroclor 1254	11097-69-1	4 06E-02	3 80E-02	3 80E-02
Aroclor 1260	11096-82-5		3 80E-02	3 80E-02
Arsenic	7440-38-2	6 08E-01	5 06E-02	5 06E-02
Barium	7440-39-3	1 42E+02		1 42E+02
Benzene	71-43-2	6 08E+00	1 38E+00	1 38E+00
alpha-BHC	319-84-6		1 20E-02	1 20E-02
beta-BHC	319-85-7		4 22E-02	4 22E-02
delta-BHC	319-86-8			
gamma-BHC (Lindane)	58-89-9	6 08E-01	5 84E-02	5 84E-02
Benzo(a)anthracene	56-55-3		1 04E-01	1 04E-01
Benzo(a)pyrene	50-32-8		1 04E-02	1 04E-02
Benzo(b)fluoranthene	205-99-2		1 04E-01	1 04E-01
Benzo(k)fluoranthene	207-08-9		1 04E+00	1 04E+00
Benzoic Acid (at pH 7)	65-85-0	8 11E+03		8 11E+03
Benzyl Alcohol	100-51-6	6 08E+02		6 08E+02
Beryllium	7440-41-7	4 06E+00		4 06E+00
bis(2-chloroethyl)ether	111-44-4		6 90E-02	6 90E-02
bis(2-chloroisopropyl)ether	39638-32-9	8 11E+01	1 08E+00	1 08E+00
bis(2-ethylhexyl)phthalate	117-81-7	4 06E+01	5 42E+00	5 42E+00
Bromodichloromethane	75-27-4	4 06E+01	1 22E+00	1 22E+00
Bromoform	75-25-2	4 06E+01	9 61E+00	9 61E+00
Bromomethane (methyl bromide)	74-83-9	2 84E+00		2 84E+00
2-Butanone (methyl ethyl ketone)	78-93-3	1 22E+03		1 22E+03
Butylbenzylphthalate	85-68-7	4 06E+02		4 06E+02
Cadmium (food)	7440-43-9			
Cadmium (water)	7440-43-9	1 01E+00		1 01E+00
Carbon disulfide	75-15-0	2 03E+02		2 03E+02
Carbon tetrachloride	56-23-5	1 42E+00	5 84E-01	5 84E-01
alpha-Chlordane	5103-71-9	1 01E+00	2 17E-01	2 17E-01
beta-Chlordane	5103-74-2	1 01E+00	2 17E-01	2 17E-01
gamma-Chlordane	12789-03-6	1 01E+00	2 17E-01	2 17E-01
4-Chloroaniline	106-47-8	8 11E+00		8 11E+00
Chlorobenzene	108-90-7	4 06E+01		4 06E+01
Chloroethane (ethyl chloride)	75-00-3	8 11E+02	2 62E+01	2 62E+01
Chloroform	67-66-3	2 03E+01		2 03E+01
Chloromethane (methyl chloride)	74-87-3		5 84E+00	5 84E+00
2-Chloronaphthalene	91-58-7	1 62E+02		1 62E+02
2-Chlorophenol	95-57-8	1 01E+01		1 01E+01
Chromium III	16065-83-1	3 04E+03		3 04E+03
Chromium VI	18540-29-9	6 08E+00		6 08E+00
Chrysene	218-01-9		1 04E+01	1 04E+01
Cobalt	7440-48-4	4 06E+01		4 06E+01

97

Table 1.4
Surface Water Screening-Level PRG Values

Target Analyte	CAS Number	[illegible]	[illegible]	[illegible]
		Noncarcinogenic Surface Water HQ = 0 1 (mg/L)	Carcinogenic Surface Water Risk = 1E-06 (mg/L)	Surface Water Risk = 1E-06 or HQ = 0 1 (mg/L)
Copper	7440-50-8	8 11E+01		8 11E+01
Cyanide	57-12-5	4 06E+01		4 06E+01
4,4-DDD	72-54-8		3 16E-01	3 16E-01
4,4-DDE	72-55-9		2 23E-01	2 23E-01
4,4-DDT	50-29-3	1 01E+00	2 23E-01	2 23E-01
Dibenz(a,h)anthracene	53-70-3		1 04E-02	1 04E-02
Dibenzofuran	132-64-9	8 11E+00		8 11E+00
Dibromochloromethane	124-48-1	4 06E+01	9 04E-01	9 04E-01
Di-n-butylphthalate	84-74-2	2 03E+02		2 03E+02
1,2-Dichlorobenzene (o-)	95-50-1	1 83E+02		1 83E+02
1,4-Dichlorobenzene (p-)	106-46-7	6 08E+01	3 16E+00	3 16E+00
3,3-Dichlorobenzidine	91-94-1		1 69E-01	1 69E-01
1,1-Dichloroethane	75-34-3	2 03E+02		2 03E+02
1,2-Dichloroethane	107-06-2	6 08E+01	8 34E-01	8 34E-01
1,1-Dichloroethene	75-35-4	1 83E+01	1 27E-01	1 27E-01
1,2-Dichloroethene (total)	540-59-0	1 83E+01		1 83E+01
2,4-Dichlorophenol (at pH 6 8)	120-83-2	6 08E+00		6 08E+00
1,2-Dichloropropane	78-87-5		1 12E+00	1 12E+00
cis-1,3-Dichloropropene	10061-01-5	6 08E+01	7 59E-01	7 59E-01
trans-1,3-Dichloropropene	10061-02-6	6 08E+01	7 59E-01	7 59E-01
Dieldrin	60-57-1	1 01E-01	4 74E-03	4 74E-03
Diethylphthalate	84-66-2	1 62E+03		1 62E+03
2,4-Dimethylphenol	105-67-9	4 06E+01		4 06E+01
Dimethylphthalate	131-11-3	2 03E+04		2 03E+04
4,6-Dinitro-2-methylphenol (4,6-dinitro-o-cresol)	534-52-1	2 03E+00		2 03E+00
2,4-Dinitrophenol	51-28-5	4 06E+00		4 06E+00
2,4-Dinitrotoluene	121-14-2	4 06E+00	1 12E-01	1 12E-01
2,6-Dinitrotoluene	606-20-2	2 03E+00	1 12E-01	1 12E-01
Di-n-octylphthalate	117-84-0	4 06E+01		4 06E+01
Endosulfan I	959-98-8	1 22E+01		1 22E+01
Endosulfan II	33213-65-9	1 22E+01		1 22E+01
Endosulfan sulfate	1031-07-8	1 22E+01		1 22E+01
Endosulfan (technical)	115-29-7	1 22E+01		1 22E+01
Endrin (technical)	72-20-8	6 08E-01		6 08E-01
Ethylbenzene	100-41-4	2 03E+02		2 03E+02
Fluoranthene	206-44-0	8 11E+01		8 11E+01
Fluorene	86-73-7	1 22E+02		1 22E+02
Heptachlor	76-44-8	1 01E+00	1 69E-02	1 69E-02
Heptachlor epoxide	1024-57-3	2 64E-02	8 34E-03	8 34E-03
Hexachlorobenzene	118-74-1	1 62E+00	4 74E-02	4 74E-02
Hexachlorobutadiene	87-68-3	4 06E-01	9 73E-01	4 06E-01
Hexachlorocyclopentadiene	77-47-4	1 22E+01		1 22E+01
Hexachloroethane	67-72-1	2 03E+00	5 42E+00	2 03E+00
Indeno(1,2,3-cd)pyrene	193-39-5		1 04E-01	1 04E-01
Iron	7439-89-6	6 08E+02		6 08E+02
Isophorone	78-59-1	4 06E+02	7 99E+01	7 99E+01
Lead	7439-92-1			4 00E+02
Lithium	7439-93-2	4 06E+01		4 06E+01
Magnesium	7439-95-4			
Manganese (nonfood)	7439-96-5	2 84E+02		2 84E+02

98

Table 1.4
Surface Water Screening-Level PRG Values

Target Analyte	CAS Number	Wildlife Receptor - Worker	Wildlife Receptor - Worker	Wildlife Receptor - Worker
		Noncarcinogenic Surface Water HQ = 0 1 (mg/L)	Carcinogenic Surface Water Risk = 1E-06 (mg/L)	Surface Water Risk = 1E-06 or HQ = 0 1 (mg/L)
Mercury (elemental)	7439-97-6			
Methoxychlor	72-43-5	1 01E+01		1 01E+01
Methylene chloride (dichloromethane)	75-09-2	1 22E+02	1 01E+01	1 01E+01
2-Methylnaphthalene	91-57-6	4 06E+01		4 06E+01
4-Methyl-2-pentanone (methyl isobutyl ketone)	108-10-1	1 62E+02		1 62E+02
2-Methylphenol (o-cresol)	95-48-7	1 01E+02		1 01E+02
4-Methylphenol (p-cresol)	106-44-5	1 01E+01		1 01E+01
Molybdenum	7439-98-7	1 01E+01		1 01E+01
Naphthalene	91-20-3	4 06E+01		4 06E+01
Nickel (soluble)	7440-02-0	4 06E+01		4 06E+01
2-Nitroaniline	88-74-4			
Nitrobenzene	98-95-3	1 01E+00		1 01E+00
4-Nitrophenol	100-02-7	1 62E+01		1 62E+01
n-Nitrosodiphenylamine	86-30-6		1 55E+01	1 55E+01
n-Nitrosodipropylamine	621-64-7		1 08E-02	1 08E-02
Pentachlorophenol	87-86-5	6 08E+01	6 33E-01	6 33E-01
Phenol	108-95-2	1 22E+03		1 22E+03
Pyrene	129-00-0	6 08E+01		6 08E+01
Selenium	7782-49-2	1 01E+01		1 01E+01
Silver	7440-22-4	1 01E+01		1 01E+01
Strontium	7440-24-6	1 22E+03		1 22E+03
Styrene	100-42-5	4 06E+02		4 06E+02
1,1,2,2-Tetrachloroethane	79-34-5	1 22E+02	3 80E-01	3 80E-01
Tetrachloroethene	127-18-4	2 03E+01	1 46E+00	1 46E+00
Tin	7440-31-5	1 22E+03		1 22E+03
Toluene	108-88-3	4 06E+02		4 06E+02
Toxaphene	8001-35-2		6 90E-02	6 90E-02
1,2,4-Trichlorobenzene	120-82-1	2 03E+01		2 03E+01
1,1,1-Trichloroethane	71-55-6	5 68E+02		5 68E+02
1,1,2-Trichloroethane	79-00-5	8 11E+00	1 33E+00	1 33E+00
Trichloroethene	79-01-6	6 08E-01	1 90E-01	1 90E-01
2,4,5-Trichlorophenol	95-95-4	2 03E+02		2 03E+02
2,4,6-Trichlorophenol	88-06-2		6 90E+00	6 90E+00
Uranium (soluble salts)	No CASN	6 08E+00		6 08E+00
Vanadium	7440-62-2	1 42E+01		1 42E+01
Vinyl acetate	108-05-4	2 03E+03		2 03E+03
Vinyl chloride	75-01-4	6 08E+00	1 05E-01	1 05E-01
Xylene (total)	1330-20-7	4 06E+03		4 06E+03
Zinc	7440-66-6	6 08E+02		6 08E+02
Nitrate	14797-55-8	3 24E+03		3 24E+03
Nitrite	14797-65-0	2 03E+02		2 03E+02
Ammonium (as Ammonia)	7664-41-7			
Fluoride (as fluorine)	7782-41-4	1 22E+02		1 22E+02
		pCi/L	pCi/L	pCi/L
Am-241	14596-10-2			4 08E+02
Pu-239	15117-48-3			3 14E+02
Pu-240	14119-33-6			3 14E+02
U-233	13968-55-3			5 91E+02
U-234	13966-29-5			6 08E+00

99

Table 1.4
Surface Water Screening-Level PRG Values

Target Analyte	CAS Number	Wildlife Refuge Worker	Wildlife Refuge Worker	Wildlife Refuge Worker
		Noncarcinogenic Surface Water HQ = 0.1 (mg/L)	Carcinogenic Surface Water Risk = 1E-06 (mg/L)	Surface Water Risk = 1E-06 or HQ = 0.1 (mg/L)
U-235	15117-96-1			6 08E+00
U-235+D	15117-96-1(+D)			6 08E+00
U-238	7440-61-1			6 08E+00
U-238+D	7440-61-1(+D)			6 08E+00

1.3 Subsurface Soil PRGs From Volatilization

The WRW subsurface soil exposure scenario associated with volatilization consists of the following pathway indoor inhalation of volatile organics emanating from subsurface soil for a WRW working at the Site for an average of 18 7 years, spending 50 percent of his or her time indoors The worker is envisioned spending all of his or her time on the most contaminated areas of the Site PRGs were calculated for both 1E-06 risk and an HQ of 0 1 The more conservative of the two values is chosen for the PRG

1.3.1 PRG Parameters and Equations

Johnson and Ettinger (EPA 2000) introduced a screening-level model that incorporates both convective and diffusive mechanisms for estimating the transport of contaminant vapors emanating from either subsurface soils or groundwater into indoor spaces located directly above the source of contamination The Johnson and Ettinger model is a one-dimensional analytical solution to convective and diffusive vapor transport into indoor spaces and provides an estimated attenuation coefficient that relates the vapor concentration in the indoor space to the vapor concentration at the source of contamination Inputs to the model include chemical properties of the contaminant, saturated and unsaturated zone soil properties, and structural properties of the building

The Johnson and Ettinger model was used to calculate PRGs associated with volatilization using site-specific and default modeling parameters The users manual for the model (Johnson & Ettinger, 2000) provides a discussion of the modeling parameters

1.3.2 Subsurface Soil Volatilization Screening-Level PRG Values

Table 1 5 presents values for the subsurface soil volatilization screening-level PRGs

Table 1.5
Subsurface Soil Volatilization Screening-Level PRG Values

Target Analyte	CAS Number	Wildlife Refuge Worker	Wildlife Refuge Worker	Wildlife Refuge Worker
		Noncarcinogenic Subsurface Soil HQ = 0 1 Site-specific VF (µg/kg)	Carcinogenic Subsurface Soil Risk = 1E-06 Site-specific VF (µg/kg)	Subsurface Soil Risk = 1E-06 or HQ = 0 1 (µg/kg)
Acenaphthene	83-32-9	1 77E+05		1 77E+05
Acetone	67-64-1	3 10E+05		3 10E+05

100

Table 1.5
Subsurface Soil Volatilization Screening-Level PRG Values

Target Analyte	CAS Number	Noncarcinogenic Subsurface Soil HQ = 0.1 Site-specific VF (µg/kg)	Carcinogenic Subsurface Soil Risk = 1E-06 Site-specific VF (µg/kg)	Subsurface Soil Risk = 1E-06 or HQ = 0 1 (µg/kg)
Aldrin	309-00-2		2 92E+05	2 92E+05
Aluminum	7429-90-5			
Anthracene	120-12-7			
Antimony	7440-36-0			
Aroclor 1016	12674-11-2			
Aroclor 1221	11104-28-2			
Aroclor 1232	11141-16-5			
Aroclor 1242	53469-21-9			
Aroclor 1248	12672-29-6			
Aroclor 1254	11097-69-1			
Aroclor 1260	11096-82-5			
Arsenic	7440-38-2			
Barium	7440-39-3			
Benzene	71-43-2		1 30E+00	1 30E+00
alpha-BHC	319-84-6		1 14E+04	1 14E+04
beta-BHC	319-85-7			
delta-BHC	319-86-8			
gamma-BHC (Lindane)	58-89-9	3 98E+05	3 82E+04	3 82E+04
Benzo(a)anthracene	56-55-3			
Benzo(a)pyrene	50-32-8			
Benzo(b)fluoranthene	205-99-2			
Benzo(k)fluoranthene	207-08-9			
Benzoic Acid (at pH 7)	65-85-0			
Benzyl Alcohol	100-51-6			
Beryllium	7440-41-7			
bis(2-chloroethyl)ether	111-44-4		6 09E+02	6 09E+02
bis(2-chloroisopropyl)ether	39638-32-9			
bis(2-ethylhexyl)phthalate	117-81-7			
Bromodichloromethane	75-27-4	8 18E+03	2 47E+02	2 47E+02
Bromoform	75-25-2	1 97E+04	4 05E+04	1 97E+04
Bromomethane (methyl bromide)	74-83-9	4 12E+01		4 12E+01
2-Butanone (methyl ethyl ketone)	78-93-3	7 37E+05		7 37E+05
Butylbenzylphthalate	85-68-7			
Cadmium (water)	7440-43-9			
Cadmium (food)	7440-43-9			
Carbon disulfide	75-15-0	2 72E+03		2 72E+03
Carbon tetrachloride	56-23-5		3 05E+01	3 05E+01
alpha-Chlordane	5103-71-9			
beta-Chlordane	5103-74-2			
gamma-Chlordane	12789-03-6			
4-Chloroaniline	106-47-8			
Chlorobenzene	108-90-7	8 57E+03		8 57E+03

Table 1.5
Subsurface Soil Volatilization Screening-Level PRG Values

Target Analyte	CAS Number	Volatile Organic Compounds (VOCs)		Volatile Organic Compounds (VOCs)
		Noncarcinogenic Subsurface Soil HQ = 0 1 Site-specific VF (µg/kg)	Carcinogenic Subsurface Soil Risk = 1E-06 Site-specific VF (µg/kg)	Subsurface Soil Risk = 1E-06 or HQ = 0 1 (µg/kg)
Chloroethane (ethyl chloride)	75-00-3	4 31E+04	1 94E+02	1 94E+02
Chloroform	67-66-3		4 71E+01	4 71E+01
Chloromethane (methyl chloride)	74-87-3	3 46E+02	1 44E+02	1 44E+02
2-Chloronaphthalene	91-58-7			
2-Chlorophenol	95-57-8	4 85E+04		4 85E+04
Chromium III	16065-83-1			
Chromium VI	18540-29-9			
Chrysene	218-01-9			
Cobalt	7440-48-4			
Copper	7440-50-8			
Cyanide	57-12-5			
4,4-DDD	72-54-8			
4,4-DDE	72-55-9			
4,4-DDT	50-29-3			
Dibenz(a,h)anthracene	53-70-3			
Dibenzofuran	132-64-9			
Dibromochloromethane	124-48-1	1 69E+04	3 77E+02	3 77E+02
Di-n-butylphthalate	84-74-2			
1,2-Dichlorobenzene (o-)	95-50-1	1 77E+05		1 77E+05
1,4-Dichlorobenzene (p-)	106-46-7			
3,3-Dichlorobenzidine	91-94-1			
1,1-Dichloroethane	75-34-3	8 65E+03		8 65E+03
1,2-Dichloroethane	107-06-2		1 07E+02	1 07E+02
1,1-Dichloroethene	75-35-4	1 05E+03		0 00E+00
1,2-Dichloroethene (total)	540-59-0			
2,4-Dichlorophenol (at pH 6 8)	120-83-2			
1,2-Dichloropropane	78-87-5	8 91E+01	1 85E+02	8 91E+01
cis-1,3-Dichloropropene	10061-01-5	1 71E+02	8 01E+01	8 01E+01
trans-1,3-Dichloropropene	10061-02-6	1 71E+02	8 01E+01	8 01E+01
Dieldrin	60-57-1		2 92E+04	2 92E+04
Diethylphthalate	84-66-2			
2,4-Dimethylphenol	105-67-9			
Dimethylphthalate	131-11-3			
4,6-Dinitro-2-methylphenol (4,6-dinitro-o-cresol)	534-52-1			
2,4-Dinitrophenol	51-28-5			
2,4-Dinitrotoluene	121-14-2			
2,6-Dinitrotoluene	606-20-2			
Di-n-octylphthalate	117-84-0			
Endosulfan I	959-98-8			
Endosulfan II	33213-65-9			
Endosulfan sulfate	1031-07-8			
Endosulfan (technical)	115-29-7			

Table 1.5
Subsurface Soil Volatilization Screening-Level PRG Values

Target Analyte	CAS Number			
		Noncarcinogenic Subsurface Soil HQ = 0 1 Site-specific VF (µg/kg)	Carcinogenic Subsurface Soil Risk = 1E-06 Site-specific VF (µg/kg)	Subsurface Soil Risk = 1E-06 or HQ = 0.1 (µg/kg)
Endrin (technical)	72-20-8			
Ethylbenzene	100-41-4	1 11E+05	3 79E+03	3 79E+03
Fluoranthene	206-44-0			
Fluorene	86-73-7	1 92E+05		1 92E+05
Heptachlor	76-44-8	1 63E+04	2 68E+02	2 68E+02
Heptachlor epoxide	1024-57-3			
Hexachlorobenzene	118-74-1			
Hexachlorobutadiene	87-68-3	1 40E+05	3 40E+04	3 40E+04
Hexachlorocyclopentadiene	77-47-4	8 12E+03		8 12E+03
Hexachloroethane	67-72-1	1 80E+04	4 81E+04	1 80E+04
Indeno(1,2,3-cd)pyrene	193-39-5			
Iron	7439-89-6			
Isophorone	78-59-1			
Lead	7439-92-1			
Lithium	7439-93-2			
Magnesium	7439-95-4			
Manganese (nonfood)	7439-96-5			
Mercury (elemental)	7439-97-6			
Methoxychlor	72-43-5			
Methylene chloride (dichloromethane)	75-09-2	7 58E+04	2 01E+03	2 01E+03
2-Methylnaphthalene	91-57-6			
4-Methyl-2-pentanone (methyl isobutyl ketone)	108-10-1	3 68E+04		3 68E+04
2-Methylphenol (o-cresol)	95-48-7			
4-Methylphenol (p-cresol)	106-44-5			
Molybdenum	7439-98-7			
Naphthalene	91-20-3	3 67E+04		3 67E+04
Nickel (soluble)	7440-02-0			
2-Nitroaniline	88-74-4			
Nitrobenzene	98-95-3	1 85E+04		1 85E+04
4-Nitrophenol	100-02-7			
n-Nitrosodiphenylamine	86-30-6			
n-Nitrosodipropylamine	621-64-7			
Pentachlorophenol	87-86-5			
Phenol	108-95-2			
Pyrene	129-00-0			
Selenium	7782-49-2			
Silver	7440-22-4			
Strontium	7440-24-6			
Styrene	100-42-5	6 82E+05		6 82E+05
1,1,2,2-Tetrachloroethane	79-34-5	1 60E+05	4 92E+02	4 92E+02
Tetrachloroethene	127-18-4		2 65E+02	2 65E+02

Table 1.5
Subsurface Soil Volatilization Screening-Level PRG Values

Target Analyte	CAS Number			
		Noncarcinogenic Subsurface Soil HQ = 0 1 Site-specific VF (µg/kg)	Carcinogenic Subsurface Soil Risk = 1E-06 Site-specific VF (µg/kg)	Subsurface Soil Risk = 1E-06 or HQ = 0 1 (µg/kg)
Tin	7440-31-5			
Toluene	108-88-3	2 50E+04		2 50E+04
Toxaphene	8001-35-2			
1,2,4-Trichlorobenzene	120-82-1	9 13E+05		9 13E+05
1,1,1-Trichloroethane	71-55-6	3 19E+04		3 19E+04
1,1,2-Trichloroethane	79-00-5	2 33E+03	3 89E+02	3 89E+02
Trichloroethene	79-01-6	1 44E+03	1 22E+01	1 22E+01
2,4,5-Trichlorophenol	95-95-4			
2,4,6-Trichlorophenol	88-06-2			
Uranium (soluble salts)	No CASN			
Vanadium	7440-62-2			
Vinyl acetate	108-05-4	2 03E+04		2 03E+04
Vinyl chloride	75-01-4	2 39E+02	1 02E+01	1 02E+01
Xylene (total)	1330-20-7			
Zinc	7440-66-6			
Nitrate	14797-55-8			
Nitrite	14797-65-0			
Ammonium (as ammonia)	7664-41-7			
Fluoride (as fluorine)	7782-41-4			

1.4 Groundwater Screening-Level PRGs From Volatilization

The WRW groundwater exposure scenario associated with volatilization consists of the following pathway indoor inhalation of volatile organics emanating from groundwater for a WRW working at the Site for an average of 18 7 years, spending 50 percent of his or her time indoors The worker is envisioned spending all of his or her time on the most contaminated areas of the Site PRGs were calculated for both 1E-06 risk and an HQ of 0 1 The more conservative of the two values is chosen for the PRG

1.4.1 PRG Parameters & Equations

As discussed in Section 1 3 1, Johnson and Ettinger (EPA 2000) introduced a screening-level model that incorporates both convective and diffusive mechanisms for estimating the transport of contaminant vapors emanating from either subsurface soil or groundwater into indoor spaces located directly above the source of contamination The model is a one-dimensional analytical solution to convective and diffusive vapor transport into indoor spaces and provides an estimated attenuation coefficient that relates the vapor concentration in the indoor space to the vapor concentration at the source of contamination Inputs to the model include chemical properties of the contaminant, saturated and unsaturated zone soil properties, and structural properties of the building

104

The Johnson and Ettinger model was used to calculate the groundwater PRGs associated with volatilization using Site-specific and default modeling parameters The users' manual for the model (Johnson & Ettinger 2000) provides a discussion of the modeling parameters

1.4.2 Groundwater Volatilization Screening Level PRG Values

Table 1 6 presents the values for the groundwater volatilization screening level PRGs

Table 1.6
Groundwater Volatilization Screening-Level PRG Values

Target Analyte	CAS Number	Noncarcinogenic Groundwater HQ = 0 1 Site-specific VF (µg/L)	Carcinogenic Groundwater Risk = 1E-06 Site-specific VF (µg/L)	Groundwater Risk = 1E-06 or HQ = 0 1 (µg/L)
Acenaphthene	83-32-9	7 04E+05		7 04E+05
Acetone	67-64-1	2 00E+06		2 00E+06
Aldrin	309-00-2	5 40E+03	3 93E+01	3 93E+01
Aluminum	7429-90-5			
Anthracene	120-12-7			
Antimony	7440-36-0			
Aroclor 1016	12674-11-2			
Aroclor 1221	11104-28-2			
Aroclor 1232	11141-16-5			
Aroclor 1242	53469-21-9			
Aroclor 1248	12672-29-6			
Aroclor 1254	11097-69-1			
Aroclor 1260	11096-82-5			
Arsenic	7440-38-2			
Barium	7440-39-3			
Benzene	71-43-2		3 41E+02	3 41E+02
alpha-BHC	319-84-6		1 30E+03	1 30E+03
beta-BHC	319-85-7			
delta-BHC	319-86-8			
gamma-BHC (Lindane)	58-89-9	5 20E+04	4 99E+03	4 99E+03
Benzo(a)anthracene	56-55-3			
Benzo(a)pyrene	50-32-8			
Benzo(b)fluoranthene	205-99-2			
Benzo(k)fluoranthene	207-08-9			
Benzoic Acid (at pH 7)	65-85-0			
Benzyl Alcohol	100-51-6			
Beryllium	7440-41-7			
bis(2-chloroethyl)ether	111-44-4		2 34E+03	2 34E+03
bis(2-chloroisopropyl)ether	39638-32-9			
bis(2-ethylhexyl)phthalate	117-81-7			

105

Table 1.6
Groundwater Volatilization Screening-Level PRG Values

Target Analyte	CAS Number	Noncarcinogenic Groundwater HQ = 0 1 Site-specific VF (µg/L)	Carcinogenic Groundwater Risk = 1E-06 Site-specific VF (µg/L)	Groundwater Risk = 1E-06 or HQ = 0 1 (µg/L)
Bromodichloromethane	75-27-4	1 62E+04	4 90E+02	4 90E+02
Bromoform	75-25-2	5 23E+04	2 54E+04	2 54E+04
Bromomethane (methyl bromide)	74-83-9	2 71E+02		2 71E+02
2-Butanone (methyl ethyl ketone)	78-93-3	4 39E+06		4 39E+06
Butylbenzylphthalate	85-68-7			
Cadmium (water)	7440-43-9			
Cadmium (food)	7440-43-9			
Carbon disulfide	75-15-0	1 83E+04		1 83E+04
Carbon tetrachloride	56-23-5		7 77E+01	7 77E+01
alpha-Chlordane	5103-71-9			
beta-Chlordane	5103-74-2			
gamma-Chlordane	12789-03-6			
4-Chloroaniline	106-47-8			
Chlorobenzene	108-90-7	6 64E+03		6 64E+03
Chloroethane (ethyl chloride)	75-00-3	3 94E+05	1 78E+03	1 78E+03
Chloroform	67-66-3		1 46E+02	1 46E+02
Chloromethane (methyl chloride)	74-87-3	4 73E+03	1 97E+03	1 97E+03
2-Chloronaphthalene	91-58-7			
2-Chlorophenol	95-57-8	1 70E+04		1 70E+04
Chromium III	16065-83-1			
Chromium VI	18540-29-9			
Chrysene	218-01-9			
Cobalt	7440-48-4			
Copper	7440-50-8			
Cyanide	57-12-5			
4,4-DDD	72-54-8			
4,4-DDE	72-55-9			
4,4-DDT	50-29-3			
Dibenz(a,h)anthracene	53-70-3			
Dibenzofuran	132-64-9			
Dibromochloromethane	124-48-1	2 88E+04	6 41E+02	6 41E+02
Di-n-butylphthalate	84-74-2			
1,2-Dichlorobenzene (o-)	95-50-1	4 49E+04		4 49E+04
1,4-Dichlorobenzene (p-)	106-46-7			
3,3-Dichlorobenzidine	91-94-1			
1,1-Dichloroethane	75-34-3	3 38E+04		3 38E+04
1,2-Dichloroethane	107-06-2		4 19E+02	4 19E+02
1,1-Dichloroethene	75-35-4	5 57E+03		5 57E+03
1,2-Dichloroethene (total)	540-59-0			
2,4-Dichlorophenol (at pH 6 8)	120-83-2			

Table 1.6
Groundwater Volatilization Screening-Level PRG Values

Target Analyte	CAS Number	[illegible]	[illegible]	[illegible]
		Noncarcinogenic Groundwater HQ = 0.1 Site-specific VF (µg/L)	Carcinogenic Groundwater Risk = 1E-06 Site-specific VF (µg/L)	Groundwater Risk = 1E-06 or HQ = 0 1 (µg/L)
1,2-Dichloropropane	78-87-5	5 05E+02	2 44E+02	2 44E+02
cis-1,3-Dichloropropene	10061-01-5	1 43E+03	6 68E-01	6 68E-01
trans-1,3-Dichloropropene	10061-02-6	1 43E+03	6 68E-01	6 68E-01
Dieldrin	60-57-1			
Diethylphthalate	84-66-2			
2,4-Dimethylphenol	105-67-9			
Dimethylphthalate	131-11-3			
4,6-Dinitro-2-methylphenol (4,6-dinitro-o-cresol)	534-52-1			
2,4-Dinitrophenol	51-28-5			
2,4-Dinitrotoluene	121-14-2			
2,6-Dinitrotoluene	606-20-2			
Di-n-octylphthalate	117-84-0			
Endosulfan I	959-98-8			
Endosulfan II	33213-65-9			
Endosulfan sulfate	1031-07-8			
Endosulfan (technical)	115-29-7			
Endrin (technical)	72-20-8			
Ethylbenzene	100-41-4	7 09E+04	2 41E+03	2 41E+03
Fluoranthene	206-44-0			
Fluorene	86-73-7			
Heptachlor	76-44-8	3 80E+01	6 25E-01	6 25E-01
Heptachlor epoxide	1024-57-3			
Hexachlorobenzene	118-74-1			
Hexachlorobutadiene	87-68-3	6 36E+01	1 55E+02	6 36E+01
Hexachlorocyclopentadiene	77-47-4	1 22E+01		1 22E+01
Hexachloroethane	67-72-1	1 41E+03	3 76E+03	1 41E+03
Indeno(1,2,3-cd)pyrene	193-39-5			
Iron	7439-89-6			
Isophorone	78-59-1			
Lead	7439-92-1			
Lithium	7439-93-2			
Magnesium	7439-95-4			
Manganese (nonfood)	7439-96-5			
Mercury (elemental)	7439-97-6			
Methoxychlor	72-43-5			
Methylene chloride (dichloromethane)	75-09-2	3 79E+00	1 00E+04	3 79E+00
2-Methylnaphthalene	91-57-6			
4-Methyl-2-pentanone (methyl isobutyl ketone)	108-10-1	1 71E+05		1 71E+05

Table 1.6
Groundwater Volatilization Screening-Level PRG Values

Target Analyte	CAS Number	Wildlife Refuge Worker	Wildlife Refuge Worker	Wildlife Refuge Worker
		Noncarcinogenic Groundwater HQ = 0.1 Site-specific VF (µg/L)	Carcinogenic Groundwater Risk = 1E-06 Site-specific VF (µg/L)	Groundwater Risk = 1E-06 or HQ = 0 1 (µg/L)
2-Methylphenol (o-cresol)	95-48-7			
4-Methylphenol (p-cresol)	106-44-5			
Molybdenum	7439-98-7			
Naphthalene	91-20-3	2 63E+03		2 63E+03
Nickel (soluble)	7440-02-0			
2-Nitroaniline	88-74-4			
Nitrobenzene	98-95-3	3 05E+04		3 05E+04
4-Nitrophenol	100-02-7			
n-Nitrosodiphenylamine	86-30-6			
n-Nitrosodipropylamine	621-64-7			
Pentachlorophenol	87-86-5			
Phenol	108-95-2			
Pyrene	129-00-0			
Selenium	7782-49-2			
Silver	7440-22-4			
Strontium	7440-24-6			
Styrene	100-42-5	1 50E+05		1 50E+05
1,1,2,2-Tetrachloroethane	79-34-5	2 02E+05	6 19E+02	6 19E+02
Tetrachloroethene	127-18-4		5 44E+02	5 44E+02
Tin	7440-31-5			
Toluene	108-88-3	2 82E+04		2 82E+04
Toxaphene	8001-35-2			
1,2,4-Trichlorobenzene	120-82-1	7 55E+04		7 55E+04
1,1,1-Trichloroethane	71-55-6	8 80E+04		8 80E+04
1,1,2-Trichloroethane	79-00-5	4 93E+03	8 24E+02	8 24E+02
Trichloroethene	79-01-6	1 78E+01	2 09E+03	1 78E+01
2,4,5-Trichlorophenol	95-95-4			
2,4,6-Trichlorophenol	88-06-2			
Uranium (soluble salts)	No CASN			
Vanadium	7440-62-2			
Vinyl acetate	108-05-4	1 11E+05		1 11E+05
Vinyl chloride	75-01-4	2 29E+03	9 75E+01	9 75E+01
Xylene (total)	1330-20-7			
Zinc	7440-66-6			
Nitrate	14797-55-8			
Nitrite	14797-65-0			
Ammonium (as ammonia)	7664-41-7			
Fluoride (as fluorine)	7782-41-4			

108

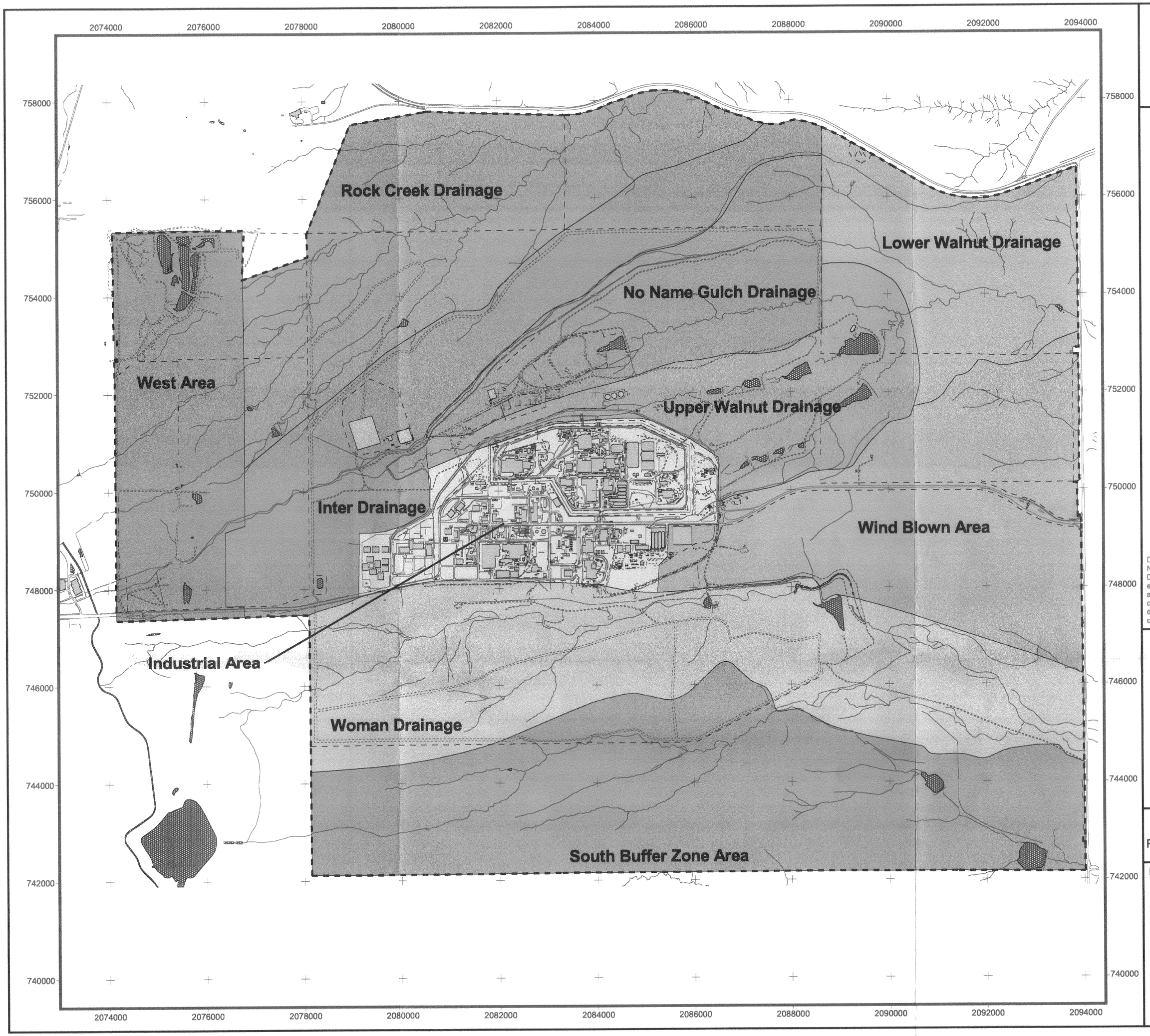
REFERENCES

DOE, EPA, and CDPHE, 1996, Rocky Flats Cleanup Agreement, Joint Agreement Between the U S Department of Energy, U S Environmental Protection Agency, Colorado Department of Public Health and Environment, and the State of Colorado, July 19

EPA, 2000, User's Guide for the Johnson and Ettinger (1991) Model for Subsurface Vapor Intrusion Into Buildings (Revised), December

EPA, CDPHE, and DOE, 2002, Task 3 Report and Appendices Calculation of Surface Radionuclide Soil Action Levels for Plutonium, Americium, and Uranium, Rocky Flats Environmental Technology Site, Golden, Colorado, September

Figure 4.1
Human Health Exposure Units



KEY

- Streams, ditches, or other drainage features
- Paved roads
- Dirt roads
- Lakes and ponds
- Fence
- Facilities
- Site Boundary

Disclaimer:
Neither the United States Government nor Kaiser-Hill, LLC, nor Dyncorp I&ET nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights.

N W E S

1500 0 1500 Feet

Scale 1: 17000

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD 27

U.S. Department of Energy
Rocky Flats Environmental Technology Site

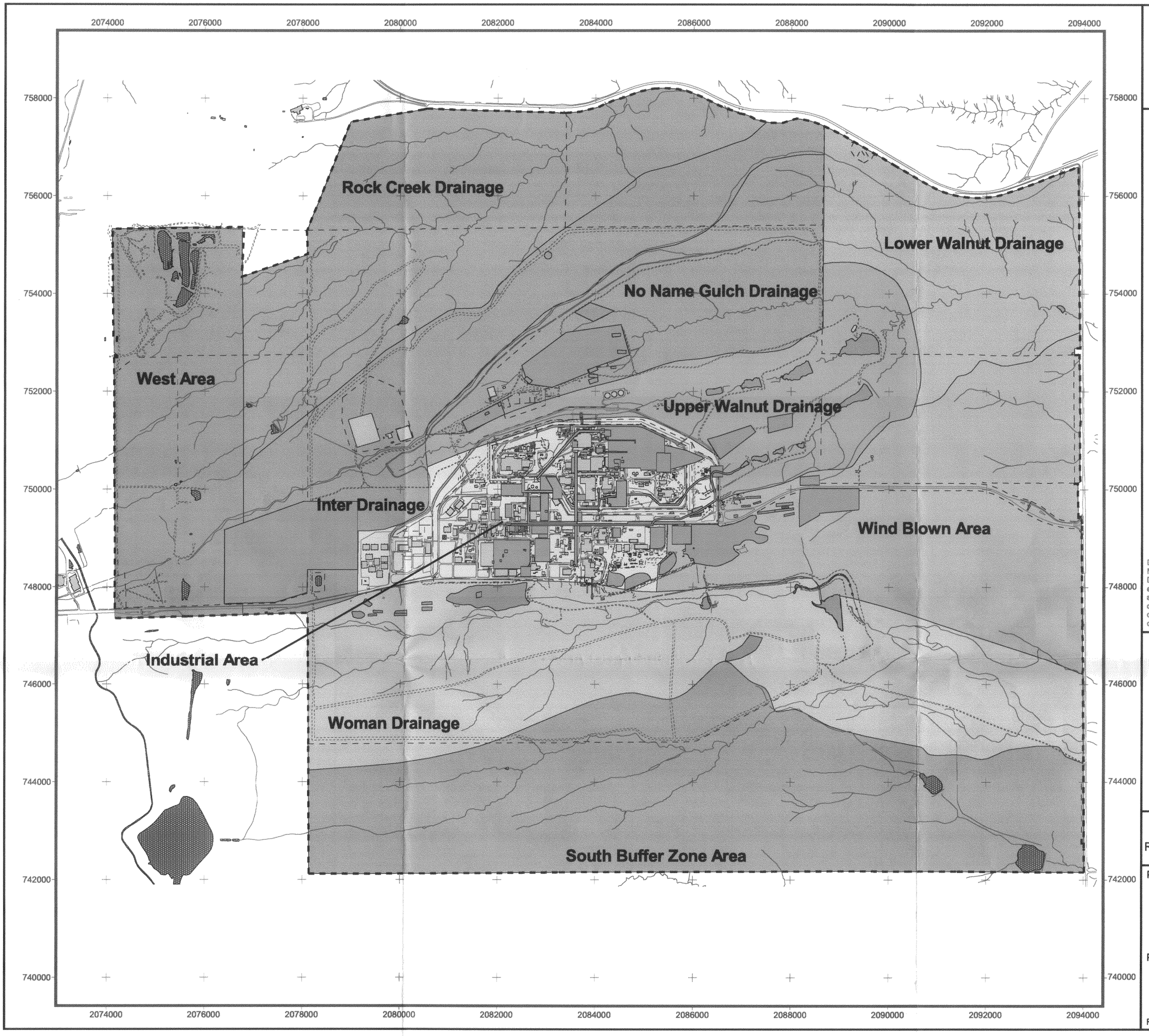
Prepared by: RADMS

Prepared for: KAISER•HILL COMPANY

File: W:\Projects\Fy2003\eco\eco.apr Date: 5.30.03

SW-A-004835 pg. 29

Figure 4.2
Exposure Units with IHSSs



KEY

- IHSS
- Streams, ditches, or other drainage features
- Paved roads
- Dirt roads
- Lakes and ponds
- Fence
- Facilities
- Site Boundary

Disclaimer:
Neither the United States Government nor Kaiser-Hill, LLC, nor Dyncorp I&ET nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights.

N
W E
S
2000 0 2000

Scale 1: 17000

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD 27

U.S. Department of Energy
Rocky Flats Environmental Technology Site

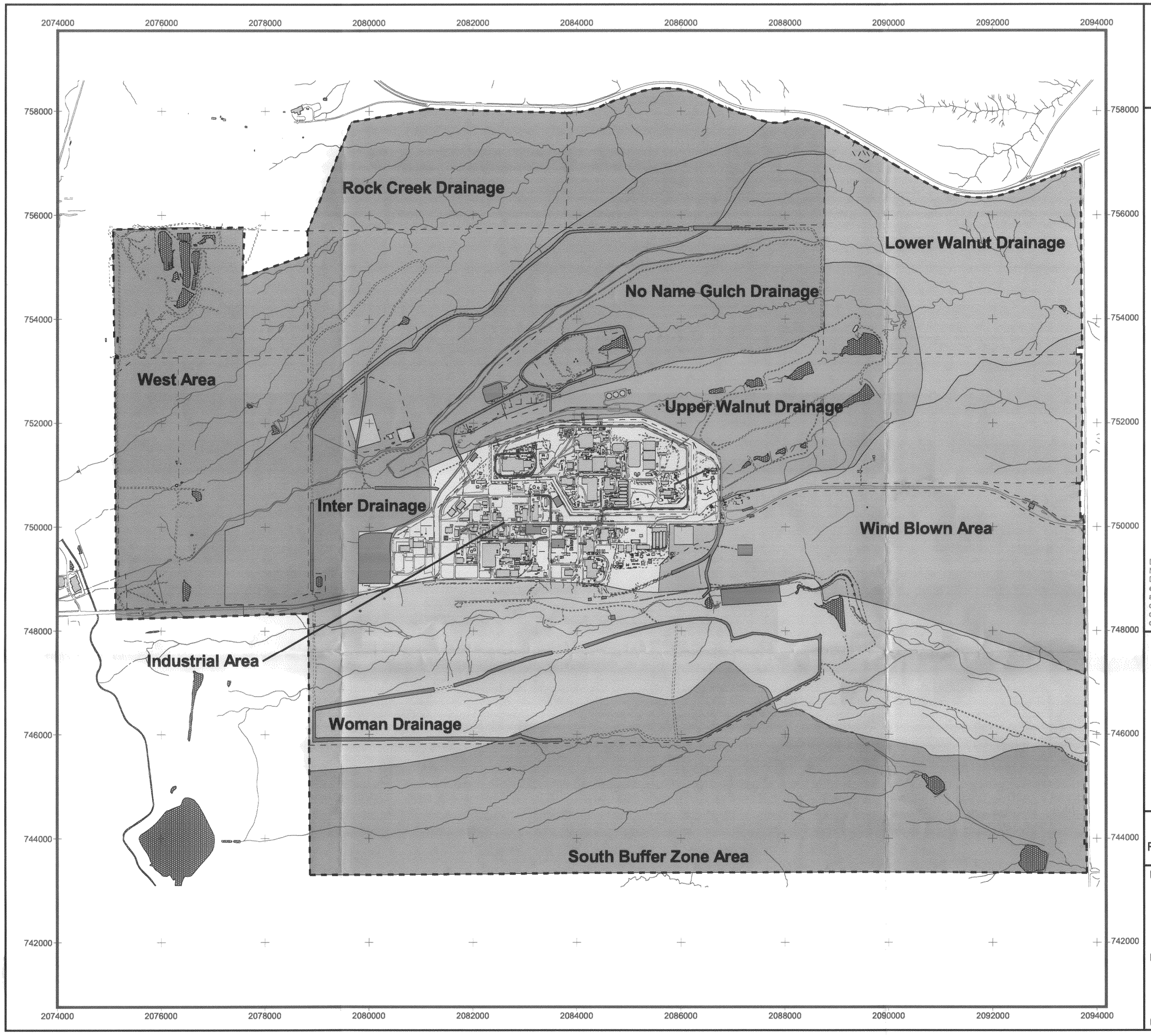
Prepared by: RADMS

Prepared for: KAISER•HILL COMPANY

File: W:\Projects\Fy2003\eco\eco.apr Date: 5.29.03

SW-A-004835 pg.31

Figure 4.3
Exposure Units with PACs



KEY

- PAC
- Streams, ditches, or other drainage features
- Paved roads
- Dirt roads
- Lakes and ponds
- Fence
- Facilities
- Site Boundary

Disclaimer:
Neither the United States Government nor Kaiser-Hill, LLC, nor Dyncorp I&ET nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights.

N W E S

1500 0 1500 Feet

Scale 1: 17,000

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD 27

U.S. Department of Energy
Rocky Flats Environmental Technology Site

Prepared by: RADMS

Prepared for: KAISER•HILL COMPANY

File: W:\Projects\Fy2003\eco\eco.apr Date: 5.30.03

SW A-004835 pg 32

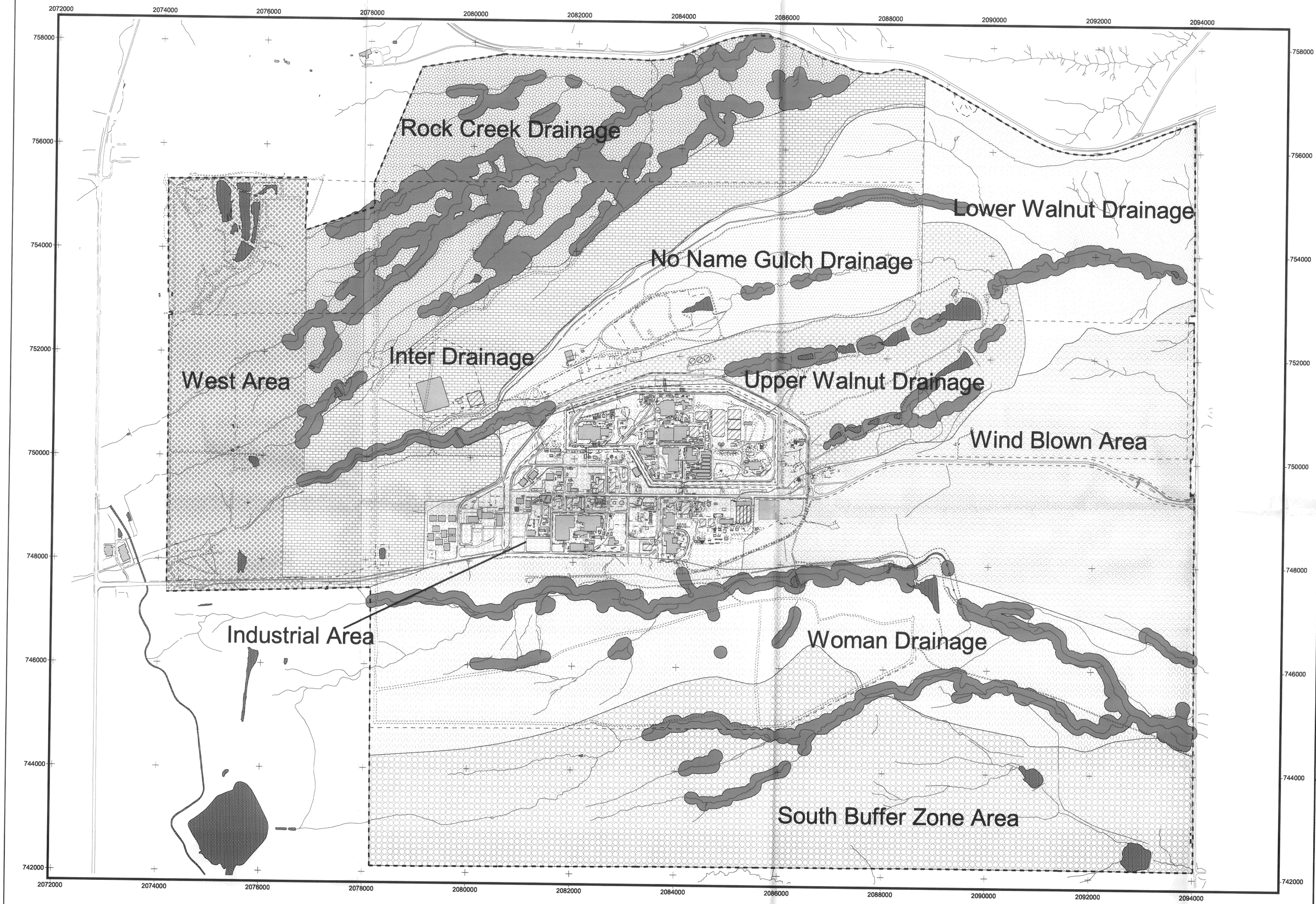


Figure 7.6
Preble's Meadow Jumping Mouse Habitat with Exposure Units

KEY

- Site Boundary
- Fence
- Pavement
- Dirt Roads
- Streams
- Lakes
- Demolished Building
- Existing Building
- PMJM Habitat
- Industrial Area
- Inter Drainage
- Lower Walnut Drainage
- No Name Gulch Drainage
- Rock Creek Drainage
- South Buffer Zone Area
- Upper Walnut Drainage
- West Area
- Wind Blown Area
- Woman Drainage

Disclaimer:
Neither the United States Government nor Kaiser-Hill, LLC, nor Dyncorp I&ET nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights.

N
W E
S

600 0 600 1200 1800 2400 3000 Feet

Scale 1:12,000

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD 27

U.S. Department of Energy
Rocky Flats Environmental Technology Site

Prepared by:
RADMS
REMEDIAL ACTION DECISION MANAGEMENT SYSTEM

Prepared for:
KAISER•HILL COMPANY

Date:09.04.03

SW-A-004835 pg. 81